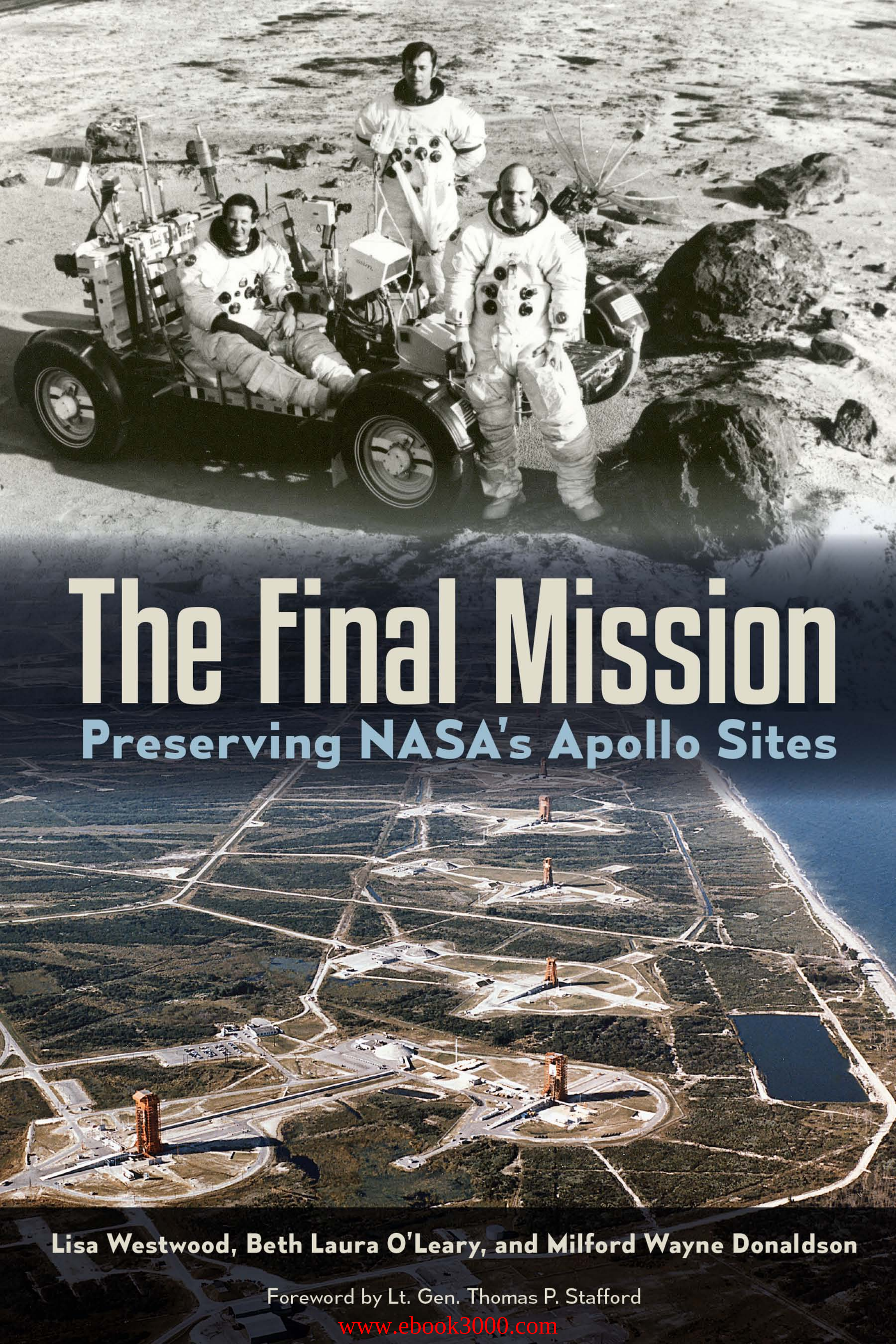

The Final Mission

Preserving NASA's Apollo Sites

Lisa Westwood, Beth Laura O'Leary, and Milford Wayne Donaldson

Foreword by Lt. Gen. Thomas P. Stafford

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Foreword

Ralph Waldo Emerson once said, "This time, like all times, is a very good one, if we but know what to do with it." With respect to our time today, this book points out that we need to look to the care and protection of some historically significant sites from our space program, to preserve them for the future. The initial phase of our journey into space, when we first left the Earth, is amazing to me as I look back to that decade of the 1960s.

As the commander of the Apollo 10 lunar mission in May 1969, I remember the first time I looked back at the Earth as we headed to the Moon. We were 30,000 miles from home when we first turned to get a glimpse at the only home humans have ever known. There it was, this beautiful blue and white globe about the size of a basketball. For the first time in all of my space flights, I felt a strange feeling of being so far from home. It was then that we knew how special this world is. Space exploration provided humans with that unique perspective never before imagined of looking back at the Earth from far away.

Our mission was to perform a full dress rehearsal of everything but the actual landing, including the first lunar orbit rendezvous. After entering lunar orbit, Gene Cernan and I separated from the command module, Charlie Brown, in the lunar module, Snoopy, to test the planned maneuvers that would later be used by Neil Armstrong and Buzz Aldrin to make the descent to the lunar surface during the subsequent Apollo 11 mission. After Gene and I finished our mapping of the future Apollo 11 path to the landing site in the Sea of Tranquility down to 9 miles above the surface, it was time to rejoin John Young in the command module for our journey home. We could not land, because our lunar module was an early block model that was too heavy to land.

Suddenly, our lunar module, Snoopy, began to roll violently. Both Mission Control and John Young stood by, helpless. While spinning out of control above the lunar surface, I managed to take over manually and separate the ascent stage from the descent stage of Snoopy early to have better control. Had we not recovered, the incident would have ended more than our lives and that of the mission. The entire U.S. space program was at risk. Humans may not have landed on the Moon that year, and we most likely would not have met President Kennedy's goal.

Space travel is, indeed, humankind's most dangerous expedition. No amount of training and research can fully alleviate the risks associated with traveling into space. As a result, in 1961, when our country prioritized the goal of landing American astronauts on the Moon, NASA could not simply achieve it with a single giant leap. A mission with risks of that magnitude—traveling into the ultimate unknown—could only be fulfilled through a series of smaller steps, each designed to bring us closer and closer to our final objective. Each of the steps, carried out by the Mercury, Gemini, and Apollo programs of the 1960s and early 1970s, challenged the human body, intellect, and spirit. The successes and failures of each mission formed our understanding of human flight and shaped the future of our space exploration programs.

Each step built on the prior developments that perfected spacecraft, launch of spacecraft, and the orbiting of Earth. As commander of Apollo 10, I depended on the knowledge gained by predecessor missions, and the new information I brought back to Earth was used to prepare Neil Armstrong, Buzz Aldrin, and Michael Collins for the first human lunar landing at Tranquility Base on July 20, 1969. However, the complexity of this collaboration of the human intellect transcended time and space; NASA was more than just the Cape and Mission Control. In a sense, NASA was one big family—one whose arms encircled thousands of scientists, engineers, mathematicians, factory workers, and support staff working at facilities all over the country over many decades. Lives were devoted, risked, and lost, all in the quest for reaching the final objective—to be the first.

By its very nature, human space exploration is filled with many "firsts." The first human to orbit the Earth, the first lunar orbit rendezvous, and the first human footsteps on the Moon are widely heralded

as milestones and historical achievements in human history. Yet each of those events was preceded by many incremental successes and failures, each significant in its own right. These steps—such as the testing and refinement of the Saturn V rocket engines used during Apollo 10, the invention of pressurized space suits, and the development of heat-resistant shields at facilities all over the country—all contributed to the mission's success. The development of each of these components was no less important to the realization of the mission. When my Apollo 10 spacecraft set a world speed record of 24,791 mph, or seven miles per second, during atmospheric reentry on May 26, 1969, no one was more grateful than I for the efforts of so many, which brought me and my crew safely home to Earth.

In retrospect, the less-known space sites and facilities, and the scientists, engineers, and technicians who worked within them, are often overlooked and underappreciated as part of the achievements of historical milestones in human space flight. As a consequence, many of these sites have fallen into disrepair or have physically vanished from the historical record. Yet without the contributions of facilities like Santa Susana Field Laboratory and White Sands Missile Range, or the sites of early rocket testing in Massachusetts and New Mexico by Robert Goddard, or the expertise of countless Oklahomans both within NASA and at facilities like the plant in Tulsa or the various contractors and subcontractors around the state and the nation, we would not be directing our attention toward a human landing on Mars today. Historic preservation of the sites and structures that represent the varied material record of our nation's space heritage is our responsibility toward future generations. It is, in the fullest sense, humanity's legacy. While we may not be able to save each and every site, the greatest honor we can bestow is to never forget them.

Lieutenant General Thomas P. Stafford, USAF (Ret.)
Pilot, Gemini 6
Commander, Gemini 9
Commander, Apollo 10
Commander, Apollo-Soyuz Test Project

Preface

Towering majestically 363 feet above the launch pad at Cape Canaveral, the Saturn V rocket stood taller than the Statue of Liberty and was more powerful than any launch vehicle previously built. Its purpose was simple: to generate enough thrust to break free from Earth's gravitational pull and hurl humans to the Moon, a quarter of a million miles away. Those who witnessed the historic liftoff on July 16, 1969, stood in awe as exhaust plumes billowed out from underneath the rocket as the Apollo 11 crew—nestled in a capsule perched delicately atop the nosecone of the rocket—appeared to slowly rise into the heavens.

The success of that mission meant more than a win for the United States on the scorecard of the Cold War space race. Entire careers had been dedicated to the research and development of the now-archaic technology needed to reach that goal, careers that exuded a passion for experimentation such that the space race was more about the internal drive to achieve success and less about the politics of the Cold War. Facilities were constructed in remote corners of the globe, in an attempt to replicate a lunar environment we knew little about, having never before experienced it. Many sites helped develop and improve the Saturn V rocket engines that carried Apollo 11 and the first humans to the moon, developed the equipment that allowed humans to survive in an oxygen-free environment, trained the astronauts, and tested the launch escape system and reentry shields on the command module. The contributions of these sites are no less important than those of Cape Canaveral or Mission Control.

Over the past several decades, spaceflight historians and archaeologists have conscientiously sifted through the dusty archives of NASA and dozens of its contractors to reconstruct the material evidence and

documentation that led up to the historic first lunar landing at Tranquility Base on July 20, 1969. Thanks to their efforts, we now know how important the research and development carried out at the places such as Santa Susana Field Laboratory and White Sands Missile Range were to the success of the Apollo mission. We better understand why Colonel Joseph Kittinger's high-altitude jump over the New Mexico desert was so critical to human survival in the vacuum of space. We can appreciate the careful thought that went into the selection of volcanic craters in remote locations for equipment prototype testing and astronaut training. But as archaeologists, historic preservationists, and historic architects, we also recognize that some aspects of history cannot be represented by the archival record alone—that the sites and structures themselves provide important information in history that is not, or cannot be, replicated elsewhere. In other words, the locations and the actual materials at these facilities and sites are just as important as the historic milestones and events that occurred therein.

The concept of in situ—the Latin phrase for "in position"—is widely recognized in the fields of archaeology and historic preservation. The term means that the original context provides clues to reconstituting the history of the site or structure. For example, an ancient Native American archaeological village site is important not just for its artifacts and abandoned pithouses but because the very location chosen for the village allowed residents access to natural resources or important trade routes to other contemporaneous sites that supported them in the first place. Accordingly, the importance of Sierra Blanca, Texas, is not just that it is associated with Neil Armstrong, Buzz Aldrin, and Jack Swigert; it only achieved that association because of the presence of a wide variety of volcanic rocks that allowed for targeted training for astronauts bound for the Moon in observing, describing, photographing, and collecting rock samples using specially designed hand tools and sample bags. These sites are important because of their characteristics and three-dimensional location on Earth and because of topography and geological resources. They include the physical matrix that surrounds them.

Now silent for decades, many facilities are abandoned structures. Countless research, astronaut training, and manufacturing facilities

and sites that dot the landscape lie unmarked, undocumented, or crumbling in ruins, failing to achieve status and recognition for their role in the historic Apollo missions. Yet without their contribution to aerospace history, the historic first human lunar landing at Tranquility Base by the Apollo 11 crew would never have occurred. Light must be shed upon these sites and less-known facilities that reflect that incredibly significant event in human history before the generation that created them passes on.

The idea for this book came about as a natural part of the evolution of the emerging field of space archaeology, initially pioneered by the authors over a decade ago. Space archaeology can be briefly defined as the systematic and scientific study of the nonrenewable material remains of human spaceflight history across time and space through the application of modern archaeological method and theory. The target consequences of such study are a better understanding of history and human behavior, the evolution of space technology, and the preservation and incorporation of that information into the existing body of knowledge. Preservation of the sites, structures, and facilities can be accommodated, where feasible, through creative historic preservation techniques such as adaptive reuse and public interpretation and detailed recording. However, considering preservation alternatives becomes possible only after these sites have been recognized, evaluated, and documented for their historic contributions and must then be balanced by other social and economic concerns, such as human health and safety and the feasibility of protecting those elements that make them important.

The importance of historic preservation of any kind of heritage must reflect the life-span of sites and properties as they transition over time from buildings, structures, features, and objects during their original use and reuse to archaeological sites after abandonment. This continuum from the built environment to the archaeological record is not often recognized as such independently by either the archaeological or the space history community, although both disciplines acknowledge that a property's importance is best explained within the historic context of that property. For this reason, this book approaches the discussion of historic preservation of space heritage sites by touching briefly

on historic architecture, history, and archaeology. This book does not attempt to encompass the totality of any of these themes, nor does it dive deeply into the political and social complexities of the times. What the authors seek to accomplish with this book is to heighten the awareness of the vast network of sites and facilities (many of which are threatened) that relate in time and function to various aspects of the human movement into space and to appeal to the public, their caretakers, and the historic preservation community to consider preservation and adaptive reuse prior to demolition to the greatest extent feasible.

The origin of the authors' passion for historic preservation of space heritage is multifaceted, blending academic and professional cultural resource management with backgrounds in archaeology, science, and engineering. Archaeologist Lisa Westwood's interest in historic preservation of space heritage originated in discussions with her college students, as is also true of coauthor Beth Laura O'Leary. She and O'Leary cofounded the Apollo 11 Preservation Task Force, a group of preservation professionals who have been working for more than a decade toward designation of Tranquility Base on the moon as a World Heritage site.

With her coauthors, Lisa Westwood led the effort to list the Objects Associated with Tranquility Base on both the California Register of Historical Resources and the New Mexico State Register of Cultural Properties, which was achieved in 2010, and has worked with members of Congress and the international community to have the site designated a National Historic Landmark (NHL). Published in the field of space history, she currently serves as the director of cultural resources for an environmental consulting firm headquartered near Sacramento, California, and is a member of the faculty in anthropology at California State University–Chico and Butte College.

Beth Laura O'Leary, PhD, began her career in space archaeology and heritage with a question from a former graduate student, Ralph Gibson, who asked during her 1999 cultural resource management seminar, "Does federal historic preservation law apply to the archaeological sites on the Moon?" With a grant from NASA through the New Mexico Space Grant Consortium, which previously had never funded an anthropological investigation, she and her students began research

on the assemblage of artifacts and features on the Moon and how they could be best preserved within the current legal framework for historic preservation. As a result of over a decade of research and chairing numerous international symposia on space heritage and several books, Dr. O'Leary was invited in 2011 to work with the NASA team on developing guidelines for preserving the scientific and historical value of NASA-owned artifacts on the Moon.

Milford Wayne Donaldson was inspired for a career in architecture and historic preservation while standing with thousands of Disneyland guests gathered in awe at the Tomorrowland Pavilion as Neil Armstrong became the first man to walk on the Moon on July 20, 1969. During his eight years as the California state historic preservation officer, Mr. Donaldson was privileged to visit many NASA, Department of Defense, and private contractor installations in an effort to preserve and interpret those less-known, but equally important, Apollo mission sites. He and his wife, Laurie, were hosted by NASA to witness the launch of STS-128, the last nighttime launch of *Discovery,* and greeted the astronauts the evening before. Along the way he had the opportunity to work with astronaut Wally Schirra as architect for the San Diego Air and Space Museum.

As NASA's program was being cut by Congress, there was an all-out effort to hold the federal government accountable for preserving those sites that best represent the extraordinary moments of our space heritage, including the Space Shuttle program. Appointed by President Obama as the chairman of the Advisory Council on Historic Preservation (ACHP), Mr. Donaldson continues to work to preserve those important moments of the Apollo program as NASA and other federal agencies begin to dispose of their surplus properties. Working with O'Leary and Westwood has been inspirational to him from the moment they stepped into his office, where they noticed a model of the lunar lander on his desk, to propose nominating the 106 objects left at Tranquility Base to the California Register of Historical Resources.

This book draws from the collective experience and expertise of the authors and their colleagues by synthesizing the concepts of historic preservation and space heritage. Toward that end, this book begins with an overarching introduction to and definition of human culture

and space heritage. Chapter 1 places the sites and facilities discussed in this book into a historic context for the Apollo program, set in the Cold War era. Chapter 2 highlights several important sites associated with the development of jet propulsion technology, and chapter 3 features key rocket testing facilities in the United States. Sites and facilities related to research and development of equipment and processes designed to protect the lives and safety of astronauts and the public are highlighted in chapter 4, and chapter 5 covers sites that were associated with astronaut training. Chapter 6 presents an overview of the relevant laws, regulations, guidelines, and international treaties that form the historic preservation framework within which preservation of space heritage occurs. Comparable mechanisms for preservation are discussed in chapter 7, and a discussion of threats to space heritage sites is provided in chapter 8. Chapter 9 provides examples of success stories that demonstrate why and how preservation can work. Chapter 10 concludes with a series of recommendations for countering threats in the present day, as well as those that are looming on the horizon.

Collectively, space heritage sites, facilities, and artifacts reflect an incredibly significant period in American and human history, and like spokes on a wheel, each was important to achieving the goal of landing a man on the Moon and bringing him safely home by the end of the 1960s. The public and the historical record remember Neil Armstrong, Buzz Aldrin, and Michael Collins but have long since forgotten the vanishing sites that reflect the historic "culture of Apollo."

Acknowledgments

This work would not have been possible without the help and support of many of our colleagues, family, and friends. We wish to sincerely thank Bill Barry of the NASA History Office, Tina Norwood and Jennifer Groman of NASA, Roger Launius, PhD, of the Smithsonian National Air and Space Museum, filmmaker Bill Moore of Oklahoma, and space historian Alan Lawrie for providing information and assistance in our research. We are grateful for the information and support provided by Jane Odom, Elizabeth Suckow, Colin Fries, Richard Spencer, and John Hargardenrader (NASA Archives); Keith Venter (NASA Ames Research Center); Christian Benitez and Steven W. Slaten (Jet Propulsion Laboratory); Merrilee Fellows (NASA); Ralph Allen (retired, Marshall Space Flight Center); Lauren Bricker, PhD (California Polytechnic University); Reymundo “Tony” Chapa and George Welsh (Edwards Air Force Base); Susan K. Stratton, PhD (formerly of the California Office of Historic Preservation); Tom McCulloch, PhD (Advisory Council on Historic Preservation); and Mark A. Beason (California Office of Historic Preservation).

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whose interest and assistance fueled our research and gave us the inspiration to preserve space heritage for future generations. Our gratitude is also extended to those who otherwise supported our efforts to preserve space heritage: the California State Historical Resources Commission; the Cultural Properties Review Committee and Historic Preservation Division of New Mexico; William Godby and Wayne Lee (White Sands Missile Range, New Mexico); Andrew R. Gomolok and George H. Ayers Jr. (Holloman Air Force Base); the New Mexico Museum of Space History; Mark Santiago (New Mexico Farm and Ranch Museum); members of the Senate and House of Representatives of the State of Hawaii; former congressman Dan Lungren and chief of staff Stacey McKinley; Bob Blackburn and Melvena Heisch (Oklahoma State Historic Preservation Office and Oklahoma History Center); Lt. Gen. Thomas P. Stafford; Katherine Slick and Jan Biella (former New Mexico state historic preservation officers); Rob Kelso (retired, NASA; Pacific International Space Center for Exploration Systems); and the countless other supporters of historic preservation of space heritage and Tranquility Base, who are too numerous to list here.

Abbreviations

AB	artifact boundary
ACHP	Advisory Council on Historic Preservation
AFB	Air Force Base
ATCM	Antarctic Treaty Consultative Meetings
CCAFS	Cape Canaveral Air Force Station
COPUOS	Committee on Peaceful Uses of Outer Space
DOD	Department of Defense
EPP	Environmental Protection Protocol
EVA	extravehicular activity
FAA	Federal Aviation Administration
FOIA	Freedom of Information Act
HAER	Historic American Engineering Record
GDSCC	Goldstone Deep Space Communications Complex
ICOMOS	International Council on Monuments and Sites
IGY	International Geophysical Year
JATO	jet-assisted takeoff
LA	Laboratory of Anthropology
LaRC	Langley Research Center
LC	launch complex
LEM	lunar excursion module
LES	launch escape system
LLRF	Lunar Landing Research Facility
LoD	Launch Operations Directorate
LOR	lunar-orbit rendezvous

NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NHL	National Historic Landmark
NHPA	National Historic Preservation Act
NRHP	National Register of Historic Places
OST	Outer Space Treaty
SCA	shuttle carrier aircraft
SHPO	state historic preservation officer
SSFL	Santa Susana Field Laboratory
STS	Space Transportation System
UNCLOS	United Nations Conference on the Law of the Sea
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USAF	United States Air Force
USC	United States Code
VAB	Vehicle Assembly Building
WHL	World Heritage List
WSMR	White Sands Missile Range
WSTF	White Sands Test Facility

Introduction

Human Culture and Space Heritage

In the most fundamental terms, space heritage is a reflection of past human culture. In 1871, British anthropologist Edward B. Tylor first used the term *culture* to embrace "the complex whole, which includes knowledge, belief, art, morals, law, customs, and any other capabilities and habits acquired by [humans] as a member of society" (Tylor 1871: 1). Many other definitions of *culture* have been advanced over the decades since then, but they all generally speak to the concept of "the complex whole." This idea evolved into a recognition by the field of anthropology that the study of human culture requires a holistic approach—one that takes into account human behavior from multiple perspectives.

The concept of holism recognizes that human societies are best studied as the systematic sums of their parts; human culture is composed of various aspects of sociology, psychology, linguistics, biology, archaeology, history, political science, and religion. In other words, human culture is a multifaceted coagulation of ideas, worldview, beliefs, experiences, places, and objects that can be understood only within its own context.

Much as the study of a society's religion cannot, in and of itself, explain the concept of marriage, the study of the archival record alone cannot solely account for the history of human space exploration. The history of human space flight is only partly documented by written documents and photographs in the archival record, only partly

explained by the political context of the Cold War space race, and only partly documented by oral histories of those who lived through some of our milestones, like the first human landing on the Moon. However, the information potential and contributions of the various physical facilities—such as rocket test stands, research and development facilities, and communications structures—that contributed to human space flight history have been underemphasized in modern historical literature. They represent the material culture of space exploration; they also physically exist. It is this important theme of "place-based" historic preservation of our space history culture that resonates throughout the following chapters.

Yet the term *human culture* is somewhat of an oxymoron. The diversity of human behavior present on Earth prohibits a single, universal definition of *culture* or *humanity.* This challenge was first tackled in the 1970s when NASA was faced with the need to summarize all of humanity on plaques affixed to Pioneer 10 and Pioneer 11 (figure I.1). Designed by Carl Sagan, the plaques were intended to relay to any extraterrestrials the spacecraft were to encounter the anatomy of a male and female human and Earth's location within the solar system.

Albert A. Harrison (2014: 175) touches upon the complexities of speaking for Earth: "Deciding what might be important to another civilization would force us to move beyond our characteristically short time span and develop a long-term perspective. Determining what we should say and how to say it could be a useful self-study that fosters self-contemplation and encourages consensus. These deliberations could clarify how we see our place in the universe, what makes us human, and where we are going."

As we turn our attention toward the universe, coming to consensus about how to define human culture to alien life forms is not easy. Among the questions raised during the development of the Pioneer plaques were fundamental ones: Should the humans be clothed? Should they hold hands? Neither portrayal is constant through time and societies on Earth.

Defining what makes us human has been the subject of anthropological discourse over the past century or more. Extensive cross-cultural research has come to the conclusion that culture is learned. Culture

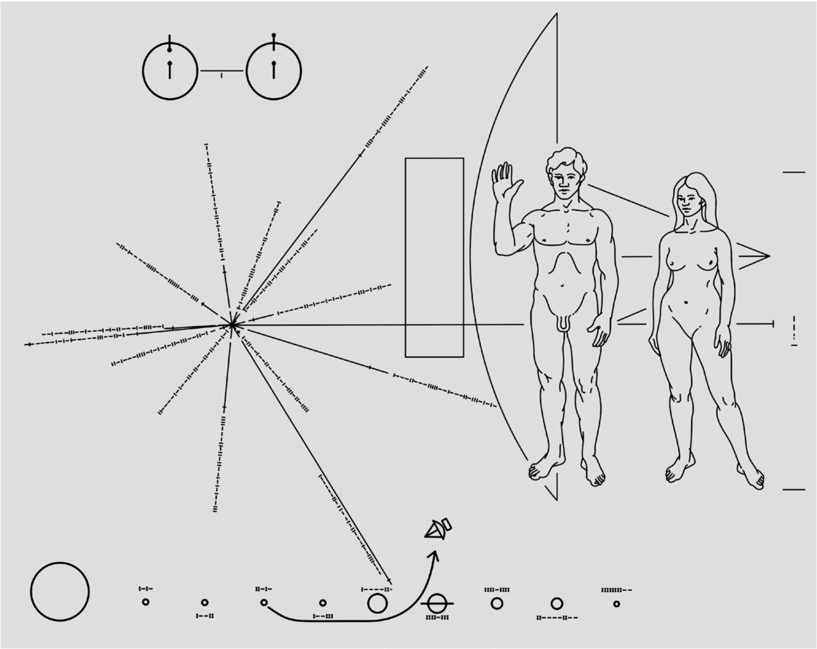

Figure I.1. Plaque depicting humans on Pioneer 10 (photo 668774, courtesy of NASA Ames).

is shared and patterned within individual societies. Culture inevitably changes. In fact, if there is any single constant in human culture, it is change.

American society in the twenty-first century is very different from that of the 1950s: much of what we do and think, from how we telephone a friend to how we communicate—even how we view the cultural construct of human "races" has changed over only a period of a half century. These changes represent only a small fraction of the explosion of cultural development that humans have achieved over the past several million years. About 3.6 million years ago, our human ancestors walked upright across volcanic mud at Laetoli in eastern Africa, recording their footsteps into the archaeological record. They figured out how to break stones to create sharp edges for cutting up game at Olduvai Gorge in East Africa 2.5 million years ago. As early as 1.6 million years ago, they had learned how to control fire. By 1969, they had honed that knowledge to use fuel-based jet propulsion technology to

Figure I.2. Human footprint on the Moon, July 20, 1969 (photo AS11-40-5878, courtesy of NASA).

propel humans to the Moon, where they recorded our first footprints among the fine lunar sediments at Tranquility Base (figure I.2).

In the almost 4 million years that passed between Laetoli and Tranquility Base, humans underwent minor anatomical changes, with the exception of increased brain size, compared to the sizeable changes to our culture. We migrated into new territory, experiencing new environments and other cultures. We learned to hunt and gather, create tools, invent language and writing, and develop religion, art, and literature. We figured out how to protect our feet on Earth and on the Moon by inventing footwear. Through archaeology, we chronicle these important achievements primarily by studying the places, artifacts, and features left behind, because in most instances, that is all we have.

Humanity is once again migrating—exploring our universe, off-Earth—and again find ourselves in unfamiliar territory. We are faced with the need to adapt to new environments, and we do this just as our ancestors did: through a process. We invent new tools, we change our behavior, and we learn from others. Cultural change is not only inevitable, it is critical to human survival.

The rate at which this process of adapting and changing our culture occurs, however, has been rapidly increasing. Anecdotal stories from former NASA employees say that there is more computerized technology present in a singing greeting card than was present in the Apollo command module. Tools and equipment for use on the Moon were designed and manufactured, but documentation was discarded so quickly that for some tools used for Apollo 11, only prototypes appear to exist on Earth. Our material culture—our artifacts—are becoming obsolete and are being replaced quickly by newer, better, and faster objects and equipment. These artifacts, similar to the written record, are creating a material record that documents not only our movement into space but also our technological and scientific advancements over time.

The development of written language that began about five thousand years ago led to our ability to document our culture's change in written form—something that our ancestors at Laetoli could not do. For example, preserved in the archives and made available to the public is the three-hundred-page "Apollo 11 Mission Report," which provides details about every aspect of the mission, from the exact mission flight schedule to how lunar rocks were sampled. Our history is being documented in written and visual form in an unprecedented manner through countless historical overviews, photographs, and videos. Unfortunately, the locations and facilities that are cited in these accounts are hidden in a sea of words. Just as important to the history of human space exploration are rocket test stands for pre-Saturn rockets, and the arroyo in southern California where jet propulsion technology was first tested, and the factories that manufactured the Apollo command module. These places receive far less attention from the historical community but were no less important to the success of the missions. Collectively, our space heritage is composed of the records, artifacts,

Figure I.3. Clovis culture spear points (replica at left, two stone bases at right), among the earliest human stone tools in North America (photo courtesy of New Mexico State University Museum).

structures, and places that chronicle the movement of humans off Earth and into space.

One of the subdisciplines of anthropology that is especially relevant to the study of the human exploration of space is archaeology. A working definition of archaeology is the study of the relationships between material culture and human behavior (Rathje and Schiffer 1980). Essentially, archaeologists study the artifacts, features, and sites that humans created and how they reflect the human activities carried out at the places they are found. Collectively, these objects and places form an archaeological record of past human behavior, which is not always replicated in a written record. More important to the subject at hand is that archaeology, by definition, is "place based."

This notion of "place-based" historic preservation is critical to the thesis advanced in this book: that our history is anchored to specific locations on Earth (or the Moon) and that the location of any given historical event often still conveys the significance of the event that occurred there. This concept is not new to heritage preservation; the idea that ancient or modern archaeological sites represent past human

activity in that specific location is integral to the discipline. In fact, it is well understood that vandalism or destruction of an archaeological site (removal of its location on the ground) is detrimental to a nonrenewable resource, and that while capturing a few artifacts and placing them into a museum is noble, doing so cannot ever fully mitigate the damage done to the site. For this reason, the discipline of archaeology can be used as an example of how "place" and "history" can be studied together to yield more information and preservation potential than either one of them alone, and this demonstrates how preservation of space heritage sites from the built environment is just as important.

This definition of archaeology does not set any spatial limitations on the discipline. Archaeology can be performed any place where humans lived. Archaeologists have investigated the sites that represent the first migration of people into North America twelve thousand years ago (O'Leary 1987) (figure I.3). Research has been carried out at the location from which a balloon was launched for the early polar exploration on Svalbard, Norway, in the early twentieth century (Capelotti 1996) (figures I.4 and I.5). Archaeologists studied the recent urban trash at Fresh Kills, New York, dating to the 1970s (Rathje and Murphy 1992). Archaeology can be performed anywhere humans have created a site and left material remains, and this is not limited to Earth by definition.

Figure I.4. Wellman Airship Base at Svalbard, Norway, in 1909 (photo courtesy of P. J. Capelotti).

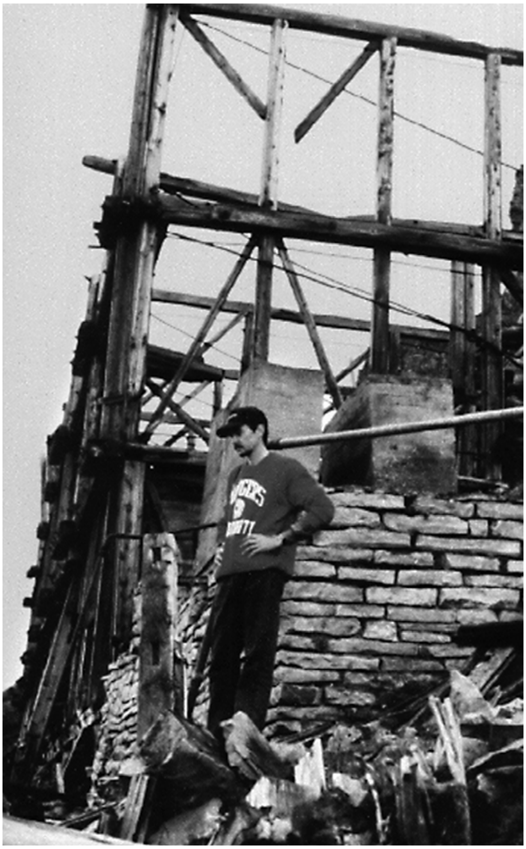

Figure I.5. Archaeologist P. J. Capelotti at Wellman Airship Base, Svalbard, Norway, 1993 (photo courtesy of P. J. Capelotti).

Because archaeology is the study of the relationship between patterns of material culture and patterns of human behavior, there are similarly no temporal limits. Many see archaeological work as necessarily restricted to investigations of the past, but others see archaeology as flexible enough to study the present or very recent past. Archaeologists are capable of studying both the past and the present and can make important contributions to knowledge about humans.

The foundations of space archaeology and heritage began with archaeologist Ben Finney, who, when exploring the technology of Polynesians settling the islands of the Pacific Ocean, suggested it might be equally important to think about space sites created by the United States and the Soviet Union (Capelotti 2009).

The best definition of space archaeology has been advanced by

Edward Staski (2009: 19): "The archaeological investigations of exoatmospheric material culture that is clearly the result of human behavior." Those exoatmospheric artifacts are part of a huge assemblage of materials that, until a certain point in time and a certain stage of development, originated on Earth but entered the archeological record somewhere else, such as another planetary body, orbit, or interstellar space. The definition can be expanded to its widest sense to encompass all material culture that relates to the development and support of activities in space (Staski and Gerke 2009). These include all the aerospace and aeronautical realms that were created by people to launch vehicles and humans into space and onto other celestial bodies. Space archaeology and heritage encompasses the archaeological record on Earth that served as an anchor to which all space materials are tied (O'Leary 2009a).

This assemblage of sites and space-related objects on Earth is enormous, but its historical significance and the need to preserve it are becoming more widely recognized, and many space objects are protected or curated in museums. The Apollo 11 Command Module, for example, which returned to Earth as part of the first lunar landing in 1969, is currently on display at the Smithsonian's National Air and Space Museum.

Places where space-related missions were developed are also recognized formally on the National Register of Historic Places (NRHP). For example, Robert Goddard's Roswell, New Mexico, ranch house and his rocket testing launch sites in Auburn, Massachusetts, are listed on the NRHP. Launch Complex 33 at White Sands Missile Range, New Mexico, where the V-2 rockets were tested and improved by Wernher von Braun, is a National Historic Landmark (NHL). The critical component of launch complexes is their actual link to the Tranquility Base site on the lunar surface. Tranquility Base is in a gray legal area with respect to preservation law. As discussed in more detail later, the objects and structures left on the Moon have recently been added to the state historical registers by the States of California and New Mexico in 2010 and the lunar site was recognized by the Hawaiian State Legislature in 2014.

Individually, these facilities and sites, scattered across Earth and beyond, possess different levels of individual merit for their contributions

to history. However, applying a systemic approach shows that the totality of these sites far exceeds the individual significance of each facility; in one sense, the whole is greater than the sum of its parts.

This concept of cultural landscape, reflecting what the authors herein advance as "Apollo culture," is not new to the field of archaeology, although only recently was it introduced into the subdiscipline of space archaeology (Gorman 2005). We use the term *Apollo culture* to discuss the six Apollo lunar landing sites and their associated sites, features, and facilities on Earth. The term is based on the premise that the cultural remains at these sites can be understood as actions of humans at a particular moment in space and time (Gorman 2016). P. J. Capelotti (2009: 424) coined the term *Apollo culture* when defining the archaeological assemblages (artifacts and footprints) left on the moon when they stopped being part of an active behavioral context, when astronauts were on the moon creating the site, and became what was left there when the astronauts left the lunar surface. Michael Schiffer (1987: 3–4) called this change from a "systemic context," referring to artifacts when they are participating in a behavioral system, to an "archaeological context" when artifacts interact only with the natural environment, such as those in a dump. Capelotti (2009) has explored the history and created a descriptive catalogue of Apollo culture. Capelotti (2009: 423) agrees with Schiffer's (1987) approach and regards the artifacts from the Apollo missions at the lunar sites as making the transition to their archaeological context "as soon as the humans vacated them." Today, because of the reliance on satellite communication, almost every human landscape on Earth interacts with space. It can be argued that globalization in the twenty-first century has been driven by the exploration and use of space.

Alice Gorman (2016: 111) extends this idea and argues that mapping and describing the distribution of the material culture of space is necessary for "a reappraisal of the mechanisms of cultural and technological change in the late industrial world." The Apollo sites can reveal motivations, national ideologies, beliefs, and customs. There can be comparisons among the six Apollo sites, such as, how did the information and practices gained on the earlier landings affect the later ones? There

can be comparisons between the Apollo human lunar landings and robotic lunar landings (Gorman 2016). If we compare the approaches of the Soviet Union to space with those of the United States, we can look at how the common requirements to survive in space overwrite or influence cultural or national differences. And we can consider how successes and failures in the past may influence the future use of and human impacts in space.

In a longer and greater historical perspective, because humans are an exploratory species, comparison can be with other exploration sites. Alice Gorman and Beth Laura O'Leary (2013: 421) have advocated that archaeologists should compare how space exploration sites are different from or similar to other past exploration sites or "how humans carry their behavior into space." Archaeological inquiry into space sites and material culture can provide a different and complimentary perspective to conventional space histories.

Moreover, Apollo culture can be expanded beyond the six lunar landing sites on the Moon. Lisa Westwood (2015) has argued, for example, that Tranquility Base would not exist were it not for the dozens of launch, communication, tracking, research and development, and manufacturing facilities and sites on Earth, the locations of which were selected to advance the mission by accommodating orbit entry and maximizing efficiency during liftoff, or to provide privacy for ongoing research and development. In taking a more holistic view of the complex system of facilities and sites, Westwood (2015: 148) proposed that all of the facilities on Earth related to the Apollo missions and human space exploration in general "were designed, functioned, or sited for specific reasons that relate to the interaction between humans and the environment, both on Earth and beyond." Each site contributes more or less to the significance of Tranquility Base. Those that convey the significance of the first human lunar landing are those that fall within the period of significance. This can be defined more broadly as the earliest experimentation with jet-assisted takeoff beginning in 1936 to the more recent shift from U.S.-government-funded exploration toward a reliance on private-sector, commercial, and international endeavors. Alternately, it can be defined more narrowly as beginning with the first

human in space (Cosmonaut Yuri Gagarin on April 12, 1961) and extending through the last Apollo mission (the return of Apollo 17 to Earth on December 19, 1972) (Westwood 2015).

In the following chapters, we begin by providing definitions for the material culture of and historic context for the Apollo program. While not exhaustive, this book provides a sample of sites from the archaeological and built environment that reflect humankind's movement into space—including some very remote sites that do not easily fit into the current historic preservation framework, which was, ironically, designed to preserve important reflections of our history.

1

Cultural Context of Apollo Culture

The Apollo culture developed amid a turbulent period in world history. At the end of World War II, the missile and rocket technology developed by the major players during the war became the basis for the exploration of space. The Space Age, in many ways, grew up in the ruins of Europe and played a critical role in the Cold War period (1946–89). In 1945, as the Allies went into Germany, both the United States and the Soviet Union (USSR) engaged in a desperate competition to acquire both German rockets and German rocket scientists (Neufeld 1996). The A-4 and V-2 rockets developed by Wernher von Braun and his engineering team in Nazi Germany later became the fundamental basis for Cold War missile technology. By the 1950s and ’60s, the descendants of the V-2 launched the first satellites and then the first humans into space and onto the Moon (Gorman and O’Leary 2007: 73). The first lunar landing site at Tranquility Base in 1969 is as much a part of the cultural heritage of the Cold War as the earliest rockets, missiles, and satellites.

The Cold War was played out in space as well as on Earth (Gorman and O’Leary 2007). In the early decades of the Cold War, the central vacuum of space—seen as devoid of atmosphere, inhabitants, history, and human culture—was where military, political, social, and technological activities took place. Howard McCurdy (1997) applies the metaphor of the western frontier to the Cold War winning of outer space. Although space has been called the “ultimate” frontier, it exists in a continuum with the concept of wilderness, which has been seen as a

moral vacuum as well as a physical one. These ideas date at least to the European colonization of the New World, where indigenous people were the "cultural" part of the physical wasteland, to which colonists would bring enlightenment, order to chaos, civilization to primitives and goodness to those who were evil (Nash 2014). As Alice Gorman and Beth Laura O'Leary (2007: 74) argue, the only significant difference between the New World wilderness and that of outer space was that there were no indigenous inhabitants with which to contend.

The idea fits also with the American ideas of nationhood and manifest destiny of that era. In the 1840s, when the American landscape was expanding beyond the original colonies, the move to include a significant portion of the North American continent was justified by an expansion "prearranged by Heaven" (Merk and Merk 1963: 24). This American mission was to redeem the sins of the Old World by creating a new world order. As Alice Gorman and Beth Laura O'Leary (2007: 75) have argued, the mission to move into space was intended to gain the allegiance of other nations by demonstrating who had the most successful scientists. In at least one sense, the United States or the Soviet Union would win both the Cold War and new territory by conquering space.

The values of early space technology are embodied in its material culture. They reflect all the players—scientific and military—and represent capitalism versus communism. The early efforts and their historic beginnings influenced the historical course of humanity's activities in space and on other celestial bodies.

The symbolism of the space race in the 1950s and '60s, and how space achievements were perceived, shaped future space policy. If the space race can be said to have culminated with NASA's Apollo program and human landings on the Moon (1969–72), then space, and particularly the Moon, is filled with the material culture of those space-faring nations involved in the Cold War. The study of this off-Earth arena with its cultural remains tethered to its terrestrial base is the proper field for archaeologists as part of humanity's evolution. One of the earliest historical events to be studied by the field of space archaeology is the competition during the International Geophysical Year (IGY) in 1957–58.

The IGY was an international scientific project organized by the International Council of Scientific Unions that began July 1, 1957, and ended December 31, 1958. It was a monumental effort of international scientific cooperation on a scale rarely seen before (Evans 1958: 30). It spanned the fields of oceanography, glaciology, seismology, meteorology, the upper atmosphere, and cosmic rays (Chapman 1959). The study of the whole Earth, particularly the Sun's influence during the anticipated heightened period of solar activity during that time, was a critical goal of the IGY (Chapman 1959). Accordingly, the International Council of Scientific Unions passed a resolution to call for the development and launch of a satellite into Earth's orbit.

Of the sixty-seven participating countries in the IGY, only a handful were already engaged in rocket research: the United States, the Soviet Union, Great Britain, Australia, Japan, and France (Wyckoff 1958: 107). Despite this, the objective of placing a satellite into Earth orbit was of enough importance that the image of a "world-circling spaceship" was incorporated into the IGY's logo.

Although international in scope, the competition provided a new arena for the United States and the Soviet Union to compete directly (Gorman and O'Leary 2007). While the United States began developing the Vanguard program, the Soviet Union quietly perfected what would later become known as Sputnik.

Sputnik 1, which was initially known in 1956 only as "Object D" or "Simple Satellite," was launched by the USSR on October 4, 1957 (figure 1.1). Its success in space was watched by the international scientific community as well as the general public, who learned to recognize the metronomic beep of Sputnik as an indicator of its success.

Amid the excitement of Sputnik being the first human object in Earth's orbit, there was also great fear of the potential for the control of space to become a military threat. A month later, in November 1957, the USSR launched the larger Sputnik 2 with a dog named Laika on board. In March 1961, the Soviets recovered two more dogs, Chernushka and Zvezdochka, from orbiting Sputniks (McNamara 2001). The USSR seemed primed to launch a human.

The early success of the USSR did not go unanswered. In July 1955, U.S. president Dwight D. Eisenhower announced approval for the

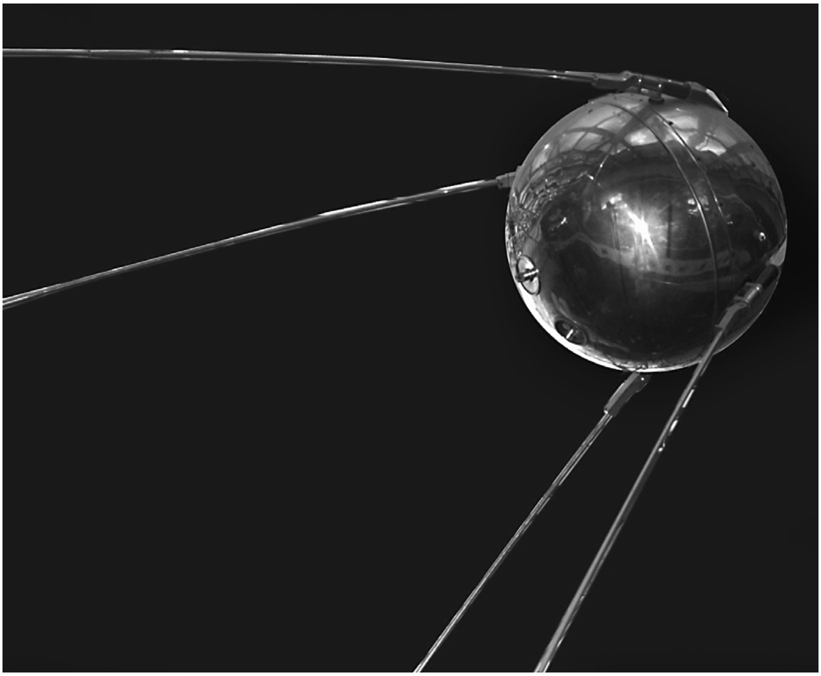

Figure 1.1. Sputnik 1 (photo courtesy of NASA).

United States' own satellite program. The U.S. Army, Air Force, and Navy all had competing projects in development, but the Naval Research Laboratory Vanguard project was based on sound rocket technology and received preference over others (von Braun and Ordway 1985: 154). In the mid-1950s, General Andrew Goodpaster told Eisenhower that a satellite could be launched in late 1956 or early in 1957, by the Redstone rocket at a modest cost of $2 million to $5 million. Eisenhower asked Goodpaster to work with Defense Secretary Charles Wilson and "speed this thing along" (Mieczkowski 2013: 53). There was a concern that the IGY satellite was not supposed to be a military enterprise and would not use resources needed for missile development, as it was considered a scientific, peaceful endeavor (Neufeld 2000: 232). Eisenhower and other military leaders were also highly aware of the implications of being second (Killian 1977: 10). While Sputnik was circling the Earth, Vanguard had its third test launch in December 1957 and blew up four feet from the ground. The press labeled it Flopnik

and Kaputnik (Killian 1977: 119). With the Soviets definitely in the lead, many Americans felt that Sputnik was an assault on national pride and a violation of manifest destiny (Killian 1977: 9). Nuclear scientist Edward Teller's reaction reflected the fears of many people when he said the United States had lost "a battle more important and greater than Pearl Harbor." When asked what might be found on the Moon, he responded "Russians" (Teller quoted in Killian 1977: 7–8).

The U.S. government had also directed its efforts toward building the military Explorer satellite. On January 31, 1958, Explorer 1 became the first U.S. satellite in orbit; Vanguard followed. Explorer 1 and 2 discovered the Van Allen radiation belts, found with instrumentation developed by scientist James Van Allen of the University of Iowa and Applied Physics Laboratory of Johns Hopkins University. When Vanguard 1 (figure 1.2) was finally successfully launched in 1958, its small (15.2 centimeter) aluminum sphere with four antennae carried no

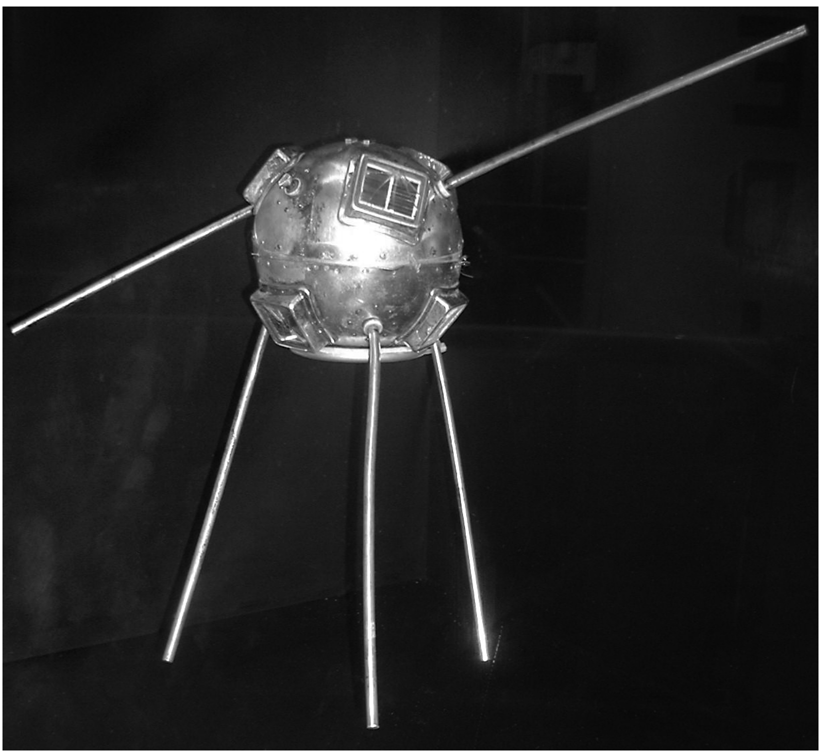

Figure 1.2. Vanguard (photo courtesy of NASA).

internal scientific instrumentation; however, observations of its orbits revealed many new facts about the Earth and its atmosphere, such as the exact shape of the Earth and cosmic ray intensity (Gorman and O'Leary 2007: 78).

These were major achievements of the IGY (Chapman 1959), but it is important to acknowledge that the American efforts were successful because of an array of sites and facilities used in cooperation to reach the final goal. It involved the satellites themselves, a launch site at Cape Canaveral, the Viking/Aerobee-based launch vehicle, and an international tracking network (Gorman and O'Leary 2007). The American IGY also created Project Moonwatch, directed by the Smithsonian Astrophysical Observatory, which had volunteers from twenty-three countries trained to provide visual observations of Vanguard's orbit—important when some of the equipment onboard failed. Amateur radio groups and stations within the United States volunteered to provide information for Project Moonwatch (Green and Lomask 1970). In addition, eight countries had established stations to receive Vanguard's radio signals. Nine countries had specially designed cameras for professional visual tracking. Australia's Woomera rocket range played an important part as being the only place to have both a radio and a visual tracking station (Gorman and O'Leary 2007). All of these people, and all of these facilities, cooperated together over great distances to ensure success. This cultural landscape is aptly named a "spacescape," incorporating the activities and their attendant facilities in support of efforts to get into space (Gorman 2003).

Vanguard was important not only because of its place in the IGY spacescape but on its own merits as well. It was not the first satellite, being preceded by Sputnik and Explorer, but all the other early satellites vanished in fiery deaths, having deorbited shortly after they were launched. Vanguard 1 remains in orbit and is currently the oldest human object in space. It even has a website that provides current tracking data (Satflare 2015). Unlike Sputnik 1, which deorbited after several months, Vanguard is expected to remain in space for another six hundred to two thousand years (Gorman and O'Leary 2007; Rogers and Darrin 2009).

Vanguard 1 is an object with both cultural and scientific significance

and is a critical part of the material record that provides evidence for the first venture off the Earth. The Vanguard team at many facilities worked on the principles and methods of thermal control and electronics (Gorman and O'Leary 2007). A major innovation in the space systems was miniaturized circuits and a new standard of efficiency for solar cells (Green and Lomask 1970). Despite not actually being the first, Project Vanguard is acknowledged as being "the progenitor of all American space exploration today" (Green and Lomask 1970: 256). The satellite is also symbolic, a material remnant representing the idea that the use of space could be cooperative and peaceful. The Purcell Committee, which advised Eisenhower, suggested in 1958 that the IGY "will suggest a model for the international exploration of space in the years and decades to come" (Purcell Committee, quoted in Gorman and O'Leary 2007: 81). While representing peaceful cooperation, Vanguard was also a participant in a battle for technological superiority and intellectual prowess between the free world and communism (Osgood 2000). Even Charles Lindbergh (1970: v) saw the significance of Vanguard as representing "a record of conflicting values, policies and ideas." This battle heightened by the early 1960s, when the United States prioritized the effort to beat the Soviets to the Moon.

Indeed, two of the most famous quotations from America's space program are Neil Armstrong's 1969 statement as he landed on the Moon for the first time and the earlier speech by President John F. Kennedy, who in a speech to Congress in 1961 urged the nation to put him there. When President Kennedy addressed the U.S. Congress regarding an American presence on the Moon, he said, "I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth" (JFK Library 2015). This directive led not only to the allocation of funding and personnel but also to an ideology that became known as Project Apollo. In a sense, Apollo culture was born that day, but its foundations had been laid decades prior.

Unlike the majority of astronauts today, the Americans that Kennedy committed to the Apollo program that day were all military men from the U.S. Army, Navy, and Marine Corps. Several were also veterans from the earlier space programs, Mercury and Gemini.

Those who went to the Moon were selected by a rotation system, affected by a series of events and luck, good or bad. In 1967, Apollo 1 astronauts Virgil I. "Gus" Grissom, Edward H. White, and Roger Chaffee were killed in a test when a fire and faulty hatch design prevented their escape. These men were treated with full military honors at their burials. It would be less than a year when Apollo 8 astronauts Frank Borman, James Lovell, and William Anders became the first humans to leave Earth's orbit and complete orbits around the Moon. The Apollo 8 flight took place after such a short time following the Apollo 1 tragedy because, according to Borman, there was an enormous drive to accomplish this before the Russians. "That's why Apollo 8's mission was changed from an Earth orbit to a lunar orbital mission: because NASA had word—from the CIA—that the Russians were going to go around the moon before the end of '68. So they changed our mission" (Borman 2001).

It is important to note that Borman, as commander of Apollo 8, recognized the risk in the changed mission but accepted it as a necessity for getting an American to the Moon before the Soviets. In the same interview, Borman stated that "the Apollo wasn't a voyage of exploration or . . . expertise in advancing technology. It was a battle in the Cold War" (Borman 2001). Facing huge risks, Apollo 8 astronauts successfully orbited the Moon, flying seventy miles above the surface to locate a place for future landings. On Christmas Eve 1968, they sent back pictures and read a biblical quotation from Genesis. When asked after they circled the Moon if it was made of Limburger cheese, astronaut Anders answered, "No, it's made of *American* cheese" (quoted in Chaikin 1994: 197 [emphasis added]).

Although Kennedy was direct in his challenge to Congress about landing a man on the Moon by the end of the 1960s, he needed public relations support to justify to the American public the expenditure of funds. Apollo 17 commander Captain Eugene A. Cernan, the last human to step foot on the Moon, reflected later,

> Along the way, totally unexpected by us, we astronauts became very visible public figures. That wasn't NASA's initial intent, but they adapted quickly. It was the press, and in turn, the public,

> who declared us "heroes," and from that followed the inevitable responsibility to "market" the space program, both to Congress and to the public that elected it. . . . It was, in part, a marketing decision that gave the world access through reports in the press and the live audio and television feeds from Houston, the Cape, and from space itself. During the high point of Apollo, the public just couldn't get enough. . . . Thus, the astronauts became the leading-edge of one of the biggest marketing efforts in history. . . . There were other marketing efforts by NASA and aerospace contractors, but no matter how intense their efforts were, the astronauts were the ones people wanted to hear and see. A personal association with someone "who had been there," is what everyone wanted. Even now we are asked the same questions we were asked decades ago: "What was it like? What did the earth look like from space? Did you feel close to God?" It may be our legacy. (quoted in Scott and Jurek 2014: vi–vii)

"Without public relations and good presentations of these programs to the public, we would have been unable to do it," said Wernher von Braun on July 22, 1969 (quoted in Siner 1969). What von Braun acknowledged as the Apollo 11 astronauts were traveling back to Earth in Command Module Columbia was that without strong public support and high-profile, enthusiastic public relations, the entire achievement and its funding would have been unthinkable. Von Braun was well aware that possible failure and catastrophe lurked a step away from every success, and that to overcome, it would require the forbearance of the press, as congressional and public support might not exist without it.

Funding proved to be one of the easiest challenges to overcome by Project Apollo. Upon Kennedy's directive, NASA's budget was fortified to a level that has never been seen since. According to NASA (2014),

> Project Apollo, backed by sufficient funding, was the tangible result of an early national commitment in response to a perceived threat to the United States by the Soviet Union. NASA leaders recognized that while the size of the task was enormous, it was still technologically and financially within their grasp, but they

> had to move forward quickly. Accordingly, the space agency's annual budget increased from $500 million in 1960 to a high point of $5.2 billion in 1965. The NASA funding level represented 5.3 percent of the federal budget in 1965. A comparable percentage of the $1.23 trillion Federal budget in 1992 would have equaled more than $65 billion for NASA, whereas the agency's actual budget then stood at less than $15 billion.

Similarly, 5.3 percent of today's federal budget of approximately $3 trillion would be $159 billion. In reality, NASA's current budget hovers around only $17 billion (NASA 2015a).

The White House and NASA surely knew that the marketing of the Moon would extend beyond the boundaries of the United States. As it turned out, the greatest technological achievement of the twentieth century was also a global event, as an estimated 600 million people worldwide watched and listened as Eagle landed on the Moon and as the first human footprints marked the lunar surface. The *New York Times* on Monday, July 21, 1969, ran a banner headline, "Men Walk on Moon," and reported that during one break in the astronauts' work, President Richard Nixon congratulated them from the White House. "Because of what you have done," the president told the astronauts, "the heavens have become part of man's world. And as you talk to us from the Sea of Tranquility, it requires us to redouble our efforts to bring peace and tranquility to Earth. For one priceless moment in the whole history of man, all the people on this earth are truly one—one in their pride in what you have done and one in our prayers that you will return safely to Earth" (Nixon 1969).

What Buzz Aldrin first described as the Moon's "magnificent desolation" gradually overtook the story of heroic exploration and the public's relationship to it. What began as epic adventure and exploration ultimately gave way to a discussion of geology, as astronaut tours became Moon rock exhibitions. Except for the unplanned "successful failure" of Apollo 13, NASA never again captured the public's imagination in the same way after Apollo 11. The event of first humans on the Moon represented the highest point of public interest in human space exploration. What once were major news events quickly became dutiful renditions

of technical details, not enough to hold the attention of broadcasters, and without that attention, space is just too expensive to fund. In a recent analysis by David Meerman Scott and Richard Jurek (2014), the reason humans have not yet been to Mars is, essentially, the result of a marketing failure.

"This will be our last TV show," said Michael Collins about the final live television transmission to the world from the crew of Apollo 11, broadcast just a few hours before splashdown. It was Wednesday night on the East Coast of the United States on July 23, 1969. "We [were] using this last opportunity to make our statement" (Collins quoted in Scott and Jurek 2014: 1).

The Apollo 11 mission dominated print, radio, and television news on Sunday, July 20, and the following day as the major networks presented continuous coverage and newspapers printed special editions and features. By that Wednesday evening on July 23, however, the networks and newspapers had returned to their regular programming and editorial schedules, with only occasional updates and reflection pieces (Collins 1974).

For many political, social, and economic reasons, interest in the Apollo program began to wane in the early 1970s. On January 5, 1972, President Richard Nixon and then NASA administrator James C. Fletcher announced the birth of the Space Shuttle program. President Nixon said,

> I have decided today that the United States should proceed at once with the development of an entirely new type of space transportation system designed to help transform the space frontier of the 1970s into familiar territory, easily accessible for human endeavor in the 1980s and '90s. This system will center on a space vehicle that can shuttle repeatedly from Earth to orbit and back. It will revolutionize transportation into near space, by routinizing it. It will take the astronomical costs out of astronautics. In short, it will go a long way toward delivering the rich benefits of practical space utilization and the valuable spinoffs from space efforts into the daily lives of Americans and all people. (Nixon 1969)

From that proclamation came a collection of five reusable space shuttles named in honor of ocean sailing vessels—these space shuttles would log thousands of hours in space and make new heroes and role models for kids of the 1980s. The technology, hardware, manpower, and almost all the reusable vehicles would become historic and subject to much study and preservation. Space Camp (opened in Huntsville, Alabama, in 1982) was originally conceived by Wernher von Braun before his death in 1977; von Braun thought there should be an experience for young people who were excited about having a career in space. The U.S. Space and Rocket Center showcases that what von Braun conceived has since hosted almost 15 million visitors. In its thirty years, his Space Camp has been experienced by more than 600,000 people (McCarter 2012). Space, after 1972, would get a new gleam to it—this time in Apollo's shadow.

The transition away from Apollo culture meant that space exploration shifted from a Cold War race to one more dedicated to scientific endeavors. This transition strengthened the opportunity for longer manned spaceflights, working with private and international partners, and extended the reaches of possibility of what humankind can do with enough resolve. In the years that followed Apollo, NASA shepherded thirty years' worth of space shuttles to orbit and back, launched the Hubble Space Telescope, and developed the Orion exploration vehicle and heavy-lift rocket, as well as the Space Launch System, at many of the sites and facilities that are highlighted in the following chapters. In the future, Orion (and the Space Launch System) is expected to be capable of sending humans to deep space destinations, such as an asteroid and eventually Mars—thereby making history again. With greater attention on the historic preservation of space heritage, we hope to be in a better position to address those milestones when they occur. All events can be most completely assessed by being viewed in the historic context of space exploration, beginning with humanity's earliest experiments.

2

Early Propulsion Development Sites and the Risks of Space Flight

Some of the most important historic sites and facilities in space heritage precede by decades the Apollo program. Events at these sites represent the foundations for human space flight and were crucial to its development.

Among all of the technological achievements developed in the first half of the twentieth century, one of the more critical to the success of the Apollo missions was jet-assisted takeoff technology. In its broadest and simplest definition, jet-assisted takeoff (JATO) is defined as the use of small rockets to propel an object into the air. The goal is quite simple: provide sufficient thrust to propel an object beyond the pull of Earth's gravitational force. "A rocket launched from Earth would need to reach a certain velocity, known as the escape velocity, to entirely escape Earth's gravity. That is, the projectile's kinetic energy is exactly equal to its potential energy at its starting position" (Donegan 2009: 83).

The challenge to achieve the escape velocity came to bear upon NASA during the development of the many stages of Saturn rockets, which ultimately led to the more powerful Saturn V rocket that took Apollo to the Moon in 1969. Today, it would seem logical that the larger and heavier the object, the more thrust and power needed to propel it into the air; the higher the elevation, the more fuel the rocket needs to accomplish its mission. Yet the complexities involved in JATO as it relates to human space flight were not solved in such a simple manner.

Generations of experimentation and research, extensive trial and error, personal sacrifice and loss of life, and a deep understanding of the laws of physics were the prerequisites to the perspective that the scientific community now possesses. Many of these lessons learned are echoed in the places left behind.

Ironically, the staggering amount of effort that was behind the development of JATO and its associated risks to human health and safety, particularly during the final stages prior to Apollo 11, was nearly invisible to the American public. Deep within the Cold War, the public's view of human space flight was colored by the fear of a Communist takeover and its domination of space as well as that of "Moon germs" that returning astronauts and rocket ships would bring to Earth (Meltzer 2011). NASA's public relations staff worked long and hard to quell public panic. On July 24, 1969, the crew of the Apollo 11 mission splashed down in the Pacific Ocean. After being rescued by the USS *Hornet,* the crew was quickly ushered across the deck of the ship to a mobile quarantine facility, a silver Airstream trailer (figure 2.1). NASA was careful to ensure that television cameras captured the workers spraying, with hospital disinfectant, the decks of the ship just seconds after the crew walked by (Meltzer 2011).

Although nothing carried from the Moon proved to be a threat to the American public, controlling public perception was critical to the continued success of the taxpayer-funded American space program. The perception among the public that JATO is both safe and simple was not necessarily orchestrated by NASA or the federal government but, rather, was a by-product of a careful public relations effort to minimize the huge risks to get into space and quell public panic. Over a period of more than a half century of intensive aerospace engineering research and development, the rose-colored glasses came off only three times.

The first incident occurred only six years after President John F. Kennedy stood before the U.S. Congress on May 25, 1961, to issue his directive to send a man to the Moon and bring him home safely before the end of the decade. On January 27, 1967, a flash fire in the command module consumed the crew of the AS-204 mission (later named Apollo 1) during a launch pad test at Cape Canaveral. Astronauts Virgil "Gus" Grissom, Edward White II, and Roger Chaffee all lost their lives

Figure 2.1. The Apollo 11 crew being ushered to the quarantine facility on the USS *Hornet* under the careful watch of decontaminating crews in 1969 (photo S69-40753, courtesy of NASA).

Figure 2.2. Apollo 1 command module after the fire of January 27, 1967 (photo S67-21295, courtesy of NASA).

during the accident. The official report on the incident concluded that the cause of the fire was related to an electrical system failure (figure 2.2) that led to an electrical arc in an oxygen-rich and flammable environment (NASA 1967). The astronaut deaths received the full attention of the public, and their heroism was emphasized in a national public funeral. Today, the skeleton of Launch Pad 34 stands as a memorial to the Apollo 1 crew. Stenciled on a wall at the site at Cape Canaveral is the phrase "abandon in place" (figure 2.3).

There were, however, several incidents, under the leadership of Eugene Kranz, the flight director, which showed how the thorough training of the flight crew, the astronauts, and engineers prepared them throughout the Apollo program. Kranz once remarked, "There's no way you could ever prove it, and yet in [Apollo] 11 we went through the—I mean, the intensity of these seconds with this group of young people, everything we'd ever done before and we were ready. In Apollo 12, we got struck by lightning, and we solved that problem in a couple

of minutes, and we were ready. In Apollo 13, we had an oxygen tank explode, and this team was ready. In Apollo 14, we had a solder ball in an abort switch as we were going to the lunar surface, waved off and came up with a software patch. Apollo 15 had again a solder ball in a switch that tried to ignite the main propulsion engine, we fixed that. And Apollo 16 had problems with the gimbels, which would have compromised the landing" (quoted in Swanson 1999: 165). This shows the dedication of each member of the team and their awareness that space flight is dangerous; as every challenge presented itself, the team was prepared to manage the crisis.

The second and third events that revealed the risks of space travel happened on January 28, 1986, and February 1, 2003, when the missions of space shuttle orbiters *Challenger* and *Columbia,* respectively, ended tragically. The *Challenger* broke apart 73 seconds into its flight after an O-ring seal in its right solid rocket booster failed in cold weather, causing the booster to separate from the shuttle and cause major structural failure. Ironically, the rubber O-rings were known to fail, but the statistical likelihood of failure on the date of the accident was underestimated. The *Columbia* disintegrated upon reentry into Earth's

Figure 2.3. Apollo 1 test stand in 2014 (photo provided by L. Westwood).

atmosphere when a piece of foam insulation broke off of an external tank and struck the left wing, allowing the heat of reentry to penetrate and destroy the wing. Again, this occurrence was known to carry risk, but the severity of the problem was underestimated or perhaps overlooked at the time (Columbia Accident Investigation Board 2003).

Investigations into the causes of these accidents, which killed all crew members aboard all three vehicles, were extensive and paralyzing to NASA. None of the accidents were found to be caused by human operational error, which could have been averted with better astronaut training. Ironically, despite the advances in JATO and human space flight by then, all three tragedies were found to be caused by design flaws, inappropriate prioritization of risks, or lack of a complete understanding of physics—and our inability to project how significant a role they played.

Centuries before humans left Earth for the first time, early scientists were leading Europe out of the Renaissance and into a time of exploding scientific, academic, and philosophical thought, now recognized as the Scientific Revolution. The fields of mathematics, chemistry, biology, physics, and astronomy made huge strides that changed the way humans think about the world around us. The fifteenth and sixteenth centuries saw mathematicians and astronomers like Nicolaus Copernicus boldly claiming a heliocentric universe—one that challenged the former geocentric, or earth-centric, model. Johannes Kepler proposed that planets move around the sun in elliptical, not circular, orbits, and Galileo Galilei made improvements to the telescope that allowed him to discover moons orbiting planets in our solar system.

In 1686, Sir Isaac Newton (1686) first published his *Philosophiæ Naturalis Principia Mathematica* (Mathematical Principles of Natural Philosophy), which brought together the three primary laws of motion. Newton's Laws of Physics, as they were later known, revealed one of the largest stumbling blocks that faced JATO: escaping the force of gravity.

Long before Newton, Copernicus, and Kepler was Heron Alexandrinus, or Hero of Alexandria, a Greek engineer and mathematician born around the year AD 10. Hero was among the first to experiment with what would later become known as JATO. His invention known as Hero's Engine (or *aeolipile*) was composed of a sphere mounted over

a kettle of water, under which a fire was started. As the fire heated the water in the kettle, steam rose through tubes and into the sphere and was released by two vents on either side.

The release of steam generated torque and thrust, which caused the sphere to rotate, demonstrating that heat could be used to propel an object. Although a good proof of the concept, it was not nearly enough to take humans off-planet, and there is little doubt that the ancient Hero failed to grasp the physics behind the phenomenon.

The real key to human spaceflight was an energy source—combustible fuel—of a kind that could generate so much thrust that objects, unlike the sphere in Hero's experiment, could be propelled into the air. The invention of gunpowder in the ninth century AD by Chinese alchemists was a huge step forward. Using one of many recipes of powdered nitrates, sulfur, and carbon, these ancient rockets were handheld, used primarily as artillery in battle. They were also highly inaccurate and exploded upon impact; neither scenario was particularly favorable for human space flight. Sir William Congreve mounted explosives on rockets that were used by the British Navy against Napoleon in 1806 and against the United States during the War of 1812 (Wicks 2000). However, the foresight of a turn-of-the-century Russian schoolteacher steered the trajectory of human space flight in an upward direction.

In 1898, Konstantin Tsiolkovsky, later deemed the father of modern astronautics, first proposed the idea of space exploration by using rockets. In his 1903 report, "The Exploration of Cosmic Space by Means of Reaction Devices," Tsiolkovsky presented his formula for achieving orbit, which later became known as the Tsiolkovsky Equation: that the horizontal speed required for a minimal orbit around the Earth is 5 miles per second and that the speed and range of a rocket were limited only by the exhaust velocity of escaping gases. To achieve greater range, he argued, one would require a multistage rocket fueled by liquid oxygen and liquid hydrogen—not by solid fuels like gunpowder. However, Tsiolkovsky's theories went untested, and unlike those who followed him, in his lifetime he never built a rocket.

Tsiolkovsky was not the only one pondering the effectiveness of liquid-based fuels. Sixty-six years before Apollo 11, the Wright brothers were making history. Three years of trials led to the first successful

flight on December 17, 1903, when a 200-pound gasoline-powered aircraft named the *Flyer* lifted Orville Wright 10 feet off the ground for a distance of over 120 feet for 12 seconds. News of that famous first "flight" over Kitty Hawk, North Carolina, spread by telegraph all over the world: for the first time, human flight actually seemed to be within reach. Their victory led to a surge of experimentation in human flight, and while the Wright brothers continued to improve upon their success—foot by foot—a young college student named Robert Hutchings Goddard was playing with fire.

Goddard was born October 5, 1882, in Worcester, Massachusetts, at a time when simple electricity was a novel and cutting-edge technology. The only surviving child of Fannie Louise Hoyt and Nahum Danford Goddard, Goddard was inspired by science fiction novels such as *War of the Worlds* by H. G. Wells and *From the Earth to the Moon* by Jules Verne. Childhood illness caused him to miss two years of high school, such that by the time he enrolled in Worcester Polytechnic Institute (WPI) in 1904 as a general science major, he was already a balding twenty-two-year-old, considerably older than his peers (Wicks 2000; Worcester Polytechnic Institute 2014a).

In retrospect, it comes as no surprise to learn that Goddard was a classic overachiever at WPI. Not only was he a straight-A student but also he was voted "Brightest Student"; elected class secretary, vice president, and president; edited the yearbook; sang in the Glee Club; and composed a school song, "Old Tech" (Worcester Polytechnic Institute 2014b). While still an undergraduate, Goddard designed and published on a gyroscope-based stabilizer for automatic control, which is now the basis for all instrument flying and automatic pilot functions on modern aircraft (Wicks 2000). His true passion, however, was in experimentation with rockets; this experimentation led to the technology that took Apollo to the Moon in 1969.

Some of his earliest experiments occurred in the basement of WPI's Salisbury Laboratories, where he measured rocket thrust. In 1907, his experimentation gained the attention of the school's administration when a cloud of smoke emerged from Salisbury after he fired the powder rocket—indoors (Worcester Polytechnic Institute 2014b). The

building still stands today, although it is not currently listed on the National Register of Historic Places (NRHP).

"Legend has it that the explosions caused some damage and he was then moved to the Magnetic Lab (now Skull Tomb). Even here, neighbors complained of hearing loud noises" (Worcester Polytechnic Institute 2014b). Surprisingly, the administration did not expel Goddard (Garner 2013), and he went on to receive a bachelor's degree in general science, with an emphasis in physics, in 1908.

In 1908, Goddard enrolled at Clark University, and by 1914, despite health complications from tuberculosis (Wicks 2000), he had earned both his master's degree and his doctorate in physics and received two U.S. patents. The first was for a multistage rocket using solid fuel (#1,102,653). However, solid fuel was problematic; as with a modern bottle rocket, there was no way to control the burn rate and thrust once ignited. In 1909, Goddard conceived the idea of a liquid-fueled rocket. With fuel in one compartment and oxygen in another, and a pressurized combustion chamber and nozzle to produce high exit velocity, he believed he could achieve a higher specific thrust. More importantly, the nozzle might allow him to control the combustion rate and, therefore, the thrust.

With this goal in mind, in 1914, he was issued his second patent—for a rocket using liquid fuel (#1,103,503). His liquid-fueled rocket was described as an "apparatus adapted for carrying explosive signals, cameras, recording instruments or other devices to unusually high altitudes" (Goddard 1914). His patent was demonstrated when he successfully launched the world's first liquid-fueled rocket from an open field on his aunt Effie's farm in Auburn, Massachusetts, on March 16, 1926 (figure 2.4).

Fueled by a $5,000 grant from the Smithsonian Institution—under the pretense that he was attempting to launch weather recording devices to altitudes higher than could be reached by weather balloons—Goddard set out to test his theories that he hoped would take rockets, and humans, all the way to the Moon (Wicks 2000).

The rocket's frame—rickety by today's standards—was built by hand, fueled by gasoline and oxygen, and dubbed "Nell" (Kluger 1999).

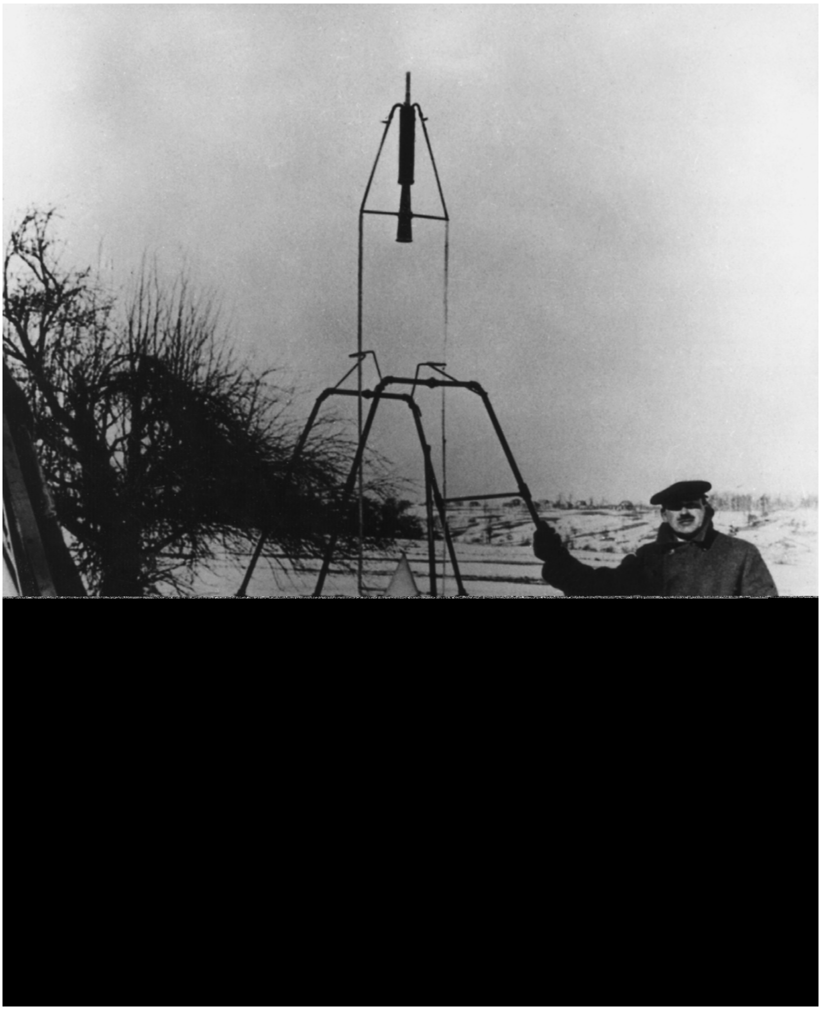

Figure 2.4. Robert H. Goddard at Auburn, Massachusetts (photo GPN-2002-000132, courtesy of NASA).

Today, a replica stands at the Air Force Space and Missile History Center at Cape Canaveral (figure 2.5).

The site he selected to test his liquid rocket in the 1930s was originally on the Asa Ward farm, now the Pakachoag Golf Course. The metal rocket, couched inside the gangly metal frame and fueled by liquid oxygen and gasoline, stood 10 feet tall. Goddard's assistant lit the fuse with a blowtorch attached to a long stick, and after an awkward silence,

the rocket launched and traveled for 2.5 seconds at a speed of about 60 miles per hour. It rose to an altitude of 41 feet above the surface before landing 184 feet away in a cabbage patch (Kluger 1999). Neighbors were not appreciative of this feat, however, having been frightened by the blast, and they notified authorities.

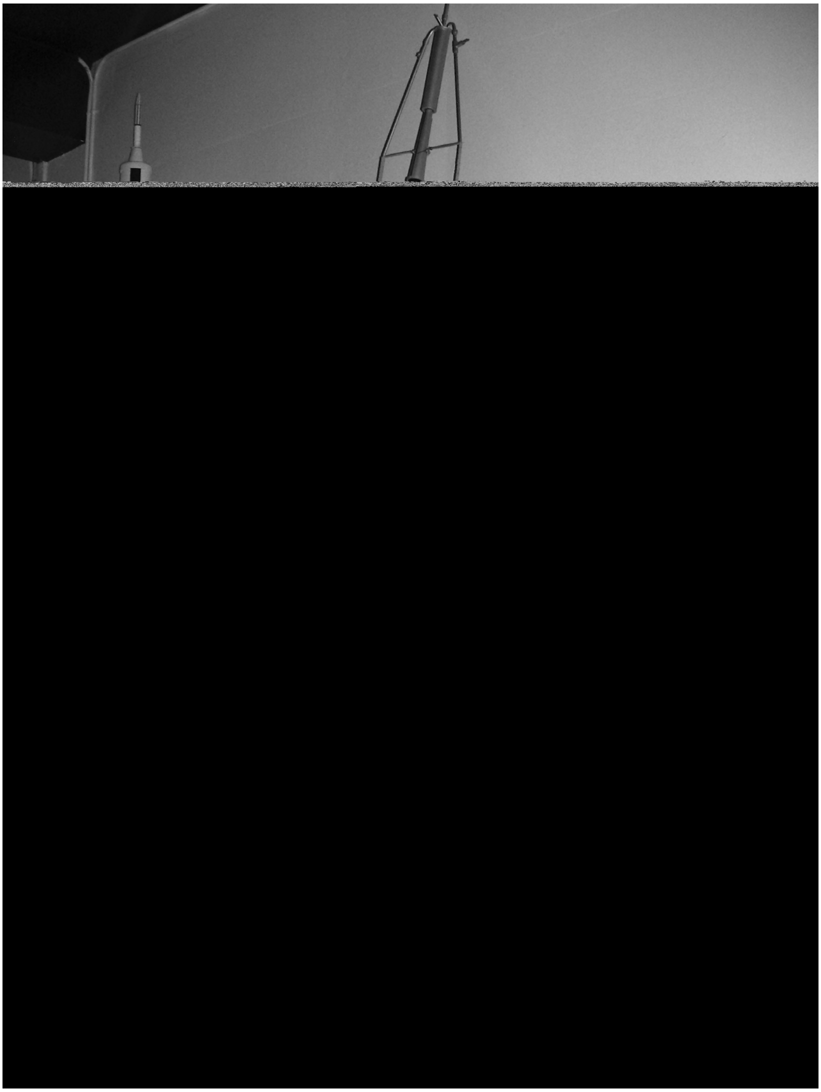

Figure 2.5. Replica of Goddard's rocket at the Air Force Space and Missile History Center at Cape Canaveral in 2014 (photo provided by L. Westwood).

The launch location, at the ninth fairway of the golf course between the tee and the green, is now marked by a plaque. A second plaque marks the location of the landing, now situated on the ninth hole near the pond.

Goddard launched another historic first flight from this location on July 17, 1929, when his 11-foot rocket carried a thermometer, an aneroid barometer, and a camera 90 feet into the air for 18.5 seconds. When the rocket landed 171 feet away by parachute, all three of the instruments were recovered. The site is now a National Historic Landmark (National Register #66000654).

In total, Goddard launched ten test flights from the farm in Massachusetts—all liquid-propellant rockets—but only four yielded flights. The last test, on June 17, 1929, ended in a crash and attracted public attention. Press responded by reporting that Goddard's moon rocket had exploded 230,000 miles short of its target (Sze and Petronis 1988).

By the late 1920s, the rocket launching had taken its toll on the neighbors, and complaints led the fire marshal to inspect the launching facilities and deem them unsafe (Wicks 2000). Goddard was banned from launching any other rockets within the boundaries of the state of Massachusetts (Sze and Petronis 1988). A temporary arrangement with the War Department between December 3, 1929, and June 30, 1930, allowed him to perform sixteen tests on proving stands—static tests but no flights—at the artillery range at Camp Devens in Massachusetts, located 15 miles from Worcester (Sze and Petronis 1988). Goddard, however, was clearly in need of a new launching area.

In a fortuitous encounter that same year, Goddard met Charles Lindbergh, who introduced him to Harry Guggenheim. With $100,000 in initial funding from the Guggenheim Foundation, Goddard moved his outdoor laboratory to southeastern New Mexico (Kluger 1999; Wicks 2000). He chose the Roswell area not only for its remoteness but also because he believed it to be a location suitable for rocket launchings. "Here on the land surrounding this house which was called the Mescalero Ranch, and on nearby ranch land, known as the Eden Valley, he set up America's first, and at the time, only rocket testing installation. The climate, the open, level terrain, and the lack of population afforded

Goddard the circumstances required to perform numerous detailed tests on ever larger rockets" (Sze and Petronis 1988).

Upon their arrival in Roswell on July 25, 1930, Goddard and his wife rented a furnished ranch house, built in 1908, at the end of a long dirt road on 8 acres just outside of town; their landlady, Miss Effie Olds of the Oldsmobile family, ultimately sold the house to the Goddards. Using funding from the Guggenheim grant, he built launching facilities, a shop, and a control tower, and he hired staff (Sze and Petronis 1988).

It was at the Mescalero Ranch where, on December 30, 1930, Goddard launched a rocket that reached an altitude of 2,000 feet and a speed of 500 miles per hour, which far exceeded any tests in Auburn, Massachusetts. Four years later, Goddard sent up the first rocket equipped with a gyroscope; it rose to 4,800 feet and traveled a horizontal distance of 13,000 feet. Overall, Goddard and his crew tested more than fifty rockets in New Mexico, developed jet vanes and gyroscopic control, and figured out the concepts of electronic propulsion, solar power, and electrostatic acceleration of ionized-gas jets.

The Goddards' house, located at 1501 East Mescalero Road in Roswell, New Mexico, is also listed on the NRHP (#85003594) (figure 2.6),

Figure 2.6. Robert H. Goddard House, Roswell, New Mexico, as photographed for the National Register of Historic Places (listing #85003594, photo courtesy of National Park Service).

and it served as his home from 1930 to 1932 and again from 1934 to 1942, the hiatus being the result of a temporary pause in Guggenheim funding caused by the Great Depression, leading Goddard to relocate back to Clark University for two years (Sze and Petronis 1988).

In July 1942, at the cusp of World War II, the U.S. Navy moved Goddard, his personnel, and his equipment to the Naval Engineering Experiment Station at Annapolis, Maryland, where he became the director of research at the Bureau of Aeronautics of the U.S. Department of the Navy (Sze and Petronis 1988). Goddard died in Baltimore of throat cancer on August 10, 1945. Although he did not live to see Apollo 11 achieve its mission in 1969, Goddard's research was clearly a prerequisite for the human landing on the Moon.

Many later less-known sites, like Goddard's, played an important role in the history of JATO research and development, which led to the success of the Apollo 11 mission. What made these places important was not only the historically significant events that occurred there but also the fact that the sites were selected because of their locations—locations that were both suitable to the activity and accommodating to the pendulum swings of research and development. Goddard himself is credited with saying, "It is not a simple matter to differentiate unsuccessful from successful experiments. Most work that is finally successful is the result of a series of unsuccessful tests in which difficulties are gradually eliminated." Even the failures and tragedies associated with finding a way to launch into space contributed to its ultimate success. The relationship between history and place is inseparable. The cultural landscape of space exploration includes a myriad of places where critical tests were undertaken so that the Apollo program would ultimately be successful.

3

Rocket Testing Sites

With a better understanding gained through rocket research and with developed technology in hand, the quest for human spaceflight was dependent upon harnessing power into rocket engines that could break free of Earth's gravitational pull. These later rockets dwarfed those of Goddard many times over, and their sheer size and weight required the construction of much larger superstructures built of flame-resistant concrete and metal. Yet the selection of rocket test stand locations was influenced by two factors: available real estate, and safety and security concerns of the Cold War. Test stands were some of the most sensitive and important sites of the time, playing a pivotal role in the space race. Ironically, given the political climate of the time, their origins were seeded by one of the most unlikely sources: Germany.

At the end of World War II, Wernher von Braun and his team of German rocket scientists, recognizing that the future war may be between the USA and the USSR, surrendered to the U.S. Army (Neufeld 2008: 203). Dubbed "Operation Paperclip," this mission was used to bring the German rocket team to the United States. While the U.S. Army continued to do rocket research as part of the Hermes project at White Sands Proving Ground, New Mexico, Fort Bliss, Texas, and Huntsville, Alabama, they assigned von Braun to assist with experimental launching and testing of repurposed, captured V-2s. Among his duties was to educate the army in the technology behind the missile, which was composed of a three-step process: engine testing in a lab, static (in place) testing of prototypes, and launch testing on a pad situated far from public view.

Von Braun's mentor, Hermann Oberth, joined the team at Huntsville in 1955 (figure 3.1). When Hermann Oberth was eleven years old, his mother gave him a copy of Jules Verne's 1865 novel *From the Earth to the Moon.* Although he studied to be a physics professor, his doctorate at Heidelberg was denied in 1922, with the note that his dissertation was too speculative for evaluation. Oberth, undeterred by the university's rejection, went on to publish his first book in 1923, *Die Rakete zu den Planetenräumen* (The Rocket into Interplanetary Space). Although Tsiolkovsky had earlier published a small portion of the content in Oberth's book, his work was unknown outside Russia at this time. German science writer Willy Ley embraced Oberth's work, and Europe became fascinated with rocketry in the 1920s.

In 1929 Fritz Lang, the renowned German film director, asked Oberth to be his technical advisor for a movie called *Frau im Mond* (Woman in the Moon). Oberth's concepts in several of the scenes prophetically depicted the space program as it would be a generation later. The dramatic countdown of "ten . . . nine . . . eight . . ." was invented along with a large assembly building that housed the "moonship," to be rolled out during darkness with floodlights enhancing the event. In addition, Oberth invented the black and white color scheme for the rockets that would reappear fifty years later as NASA's Saturn V. Oberth's drawings showed multiple stages with clustered liquid-fueled rocket engines powering a bullet-shaped rocket (Reynolds 2013: 23). In late 1929, Oberth conducted his first static firing, named Kegelduse, a liquid-fueled rocket motor. An eighteen-year-old Wernher von Braun assisted him (Swanson 1999: 41).

In 1941, Oberth moved to Peenemunde to work on the Aggregate Rocket program. He visited the V-2 facilities sometime in late 1943, and it became apparent that von Braun had not been building the ideal military missile but a prototype of a space rocket, the A-4. Although von Braun was arrested for squandering war resources on the A-4 instead of the V-2, he was quickly released from prison through the intervention of Albert Speer with Adolf Hitler. As the U.S. Army moved into Germany, von Braun and his team quickly surrendered in Operation Paperclip. After World War II ended, Oberth moved from Nuremberg to Switzerland in 1948 as a writer, and eventually he returned to the

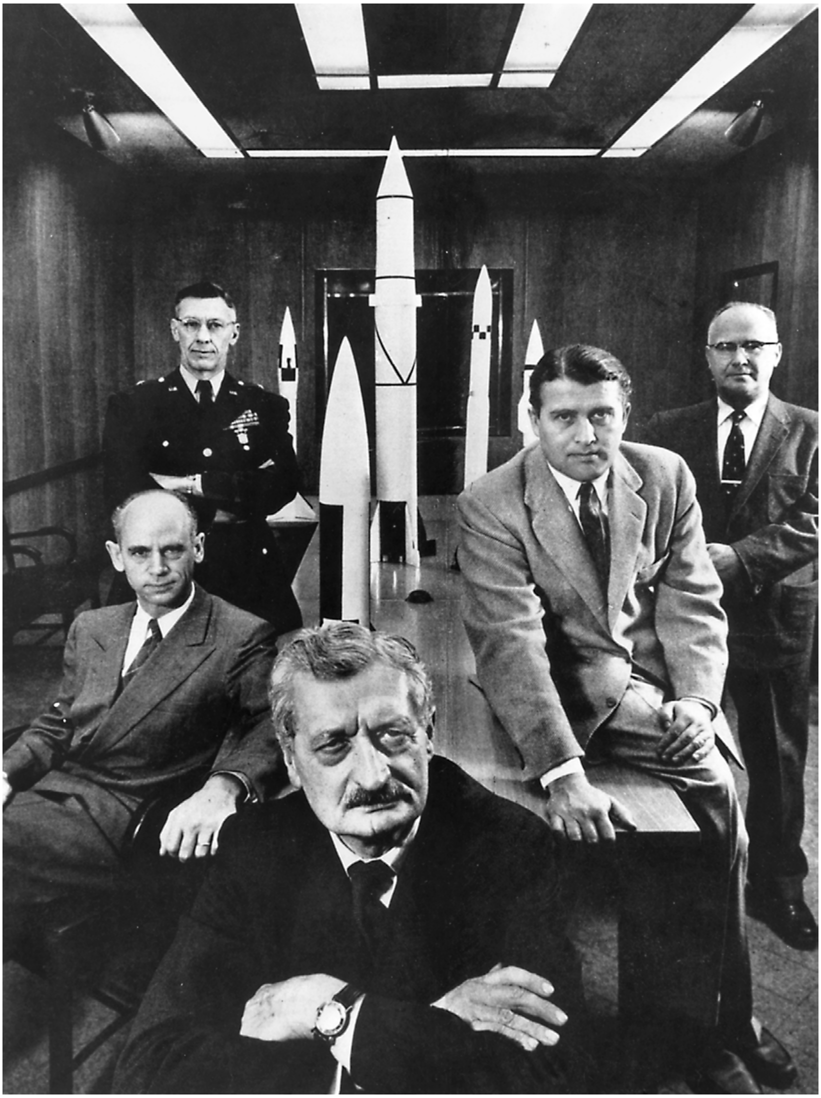

Figure 3.1. Hermann Oberth (*forefront*) with Major General H. N. Toftoy, Ernst Stuhlinger, Wernher von Braun, and Dr. Robert Lusser of the Army Ballistic Missile Agency at Huntsville, Alabama, in 1956 (photo NASA 16316242630_3e3443e384, courtesy of NASA).

Figure 3.2. Redstone Propulsion Test Stand during the installation of a Mercury capsule and escape system at Marshall Space Flight Center, 1960 (photo courtesy of NASA).

United States to work for his former student, Wernher von Braun, in Huntsville, Alabama (Rauschenbach 1994).

In 1950, the army moved its missile research facilities and its German scientists from Fort Bliss to the Ordinance Guided Missile Center near Huntsville, Alabama—a location that ultimately would become one of the hubs of space exploration. There, they developed various rockets that could carry the heavier payload needed to support the escalating

Korean conflict, and they then continued to develop and test rocket engines that would eventually carry humans into space. Three sites in Huntsville, all at what is now called Marshall Space Flight Center, are particularly notable: the Redstone Test Stand, the Propulsion and Structural Test Facility, and the Saturn V Dynamic Test Stand (Neufeld 2005).

The initial program was called “Redstone” and used von Braun’s team and their unique process of testing rockets. Because a propulsion test stand was needed to test the first twelve missiles, and congressional funding was slow, they improvised. The team first constructed the concrete base for the test stand with a modest budget of $25,000, the most money allowed for a single project by Congress. The resulting test stand, completed in the spring of 1953, reflected the tight budget (figure 3.2).

Metal structural members were salvaged from around the military base to construct the stand. To enable the firings to be viewed, three railroad tankers, once used to carry chemicals, were repurposed, cleaned, and buried away from the test stand to serve as observation bunkers. Two surplus army tanks supplied the periscopes to help view the firings.

The Redstone Test Stand ran 362 static firing tests between 1953 and 1961 to improve the propulsion system; 200 of these tests led directly to improvements in the rocket used for the Mercury manned flight program that carried the first American astronaut into space, Alan Shepard (National Park Service 2015). Unlike many other rocket test stands, it was not extensively remodeled to fit later rockets, and thus it retains the original feel of the Redstone era. The Redstone Test Stand is now a National Historic Landmark (NHL) (figure 3.3).

John Collins, a senior specialist in national defense at the Congressional Research Service of the Library of Congress, was asked in June 1987 to prepare “a frame of reference that could help Congress evaluate future, as well as present, military space policies, programs, and budgets.” One of the U.S. senators, former astronaut John Glenn, was instrumental in crafting this analysis. The document focused on the Earth-Moon system, because interplanetary combat seemed far in the future. Although heavily based on perceived threats from outer space

Figure 3.3. Redstone Test Stand with missile, and cold calibration unit at the left, circa 2009 (photo courtesy of the Carol M. Highsmith Archive Collection, U.S. Library of Congress).

and possible bases on the Moon, the analysis promoted the Outer Space Treaty of 1967, which forbids weapons of mass destruction in space and military activities on the Moon and other celestial bodies (Collins 1989: 141).

As the focus of rocket testing added another objective beyond the military one—that of human space flight—test stands were being built for rockets that could take on heavier and heavier payloads. The Propulsion and Structural Test Facility, built by the Army Ballistic Missile

Agency at Huntsville in 1957 (figure 3.4), became the primary center of development for rocket propulsion systems and vehicles (NPS 2015). Here, von Braun directed the development of the family of launch vehicles during the early phases of the U.S. space program, including the testing of the army's Redstone rocket, the Saturn S-IB vehicle, and the Saturn 1-C vehicle used in the Apollo program (NPS 2015). It is considered one of the most important facilities of the U.S. space program and is an NHL (figure 3.5).

However, the launch of Sputnik 1 in 1957 by the USSR refocused the American program and speeded up the testing of and modifications to the Jupiter-C class vehicles. Two Jupiter-C class missiles were used, and the vehicle was renamed Juno 1. On January 31, 1958, Explorer 1 was placed into orbit by Juno 1, following modifications to the Interim Test Stand, showing how quickly engineers could repurpose launch facilities.

The massive Saturn V Dynamic Test Stand was used in 1966 and 1967 for ground vibration testing of the Saturn V launch vehicle and

Figure 3.4. Testing the F-1 engine, the most powerful rocket engine ever fired at Marshall Space Flight Center, circa 1957 (photo courtesy of NASA/MSFC).

Figure 3.5. Propulsion and Structural Test Facility in 2010 (photo courtesy of the Carol M. Highsmith Archive Collection, U.S. Library of Congress).

the Apollo spacecraft. Completion of this program was one of the final steps prior to the launch of Apollo 11, and the test stand was used for later missions (figure 3.6).

Although the rocket was not intended to be flown, it was a working vehicle that prepared the way for the Apollo expeditions to the moon (NASA 2015b). The Dynamic Test Stand was a major contributor in the Apollo program, because the rockets tested at the facility launched the first two American astronauts, Alan Shepard and later, Virgil Grissom, into space. The site was restored for the U.S. Bicentennial and was declared an NHL in 1985.

While rocket testing was ongoing in Alabama, most of the launch facilities were being built at Cape Canaveral Air Force Station (CCAFS) in Florida. CCAFS remains one of the most iconic historic space exploration facilities. It was originally established as part of the Air Force Space Command's Forty-Fifth Space Wing, headquartered at nearby Patrick Air Force Base. It was known as Cape Canaveral from 1949 to 1963 and as Cape Kennedy from 1963 to 1973 (figure 3.7).

The first rocket to be launched at Cape Canaveral was the Bumper 8, a two-stage rocket that topped a V-2 missile base with a WAC Corporal

rocket. Under the direction of General Electric, the Bumper project was used for testing rocket systems and for research in the upper atmosphere for air temperature and cosmic ray impacts (figure 3.8).

Cape Canaveral is, perhaps, even more well recognized by the American public than the more recent and adjacent facility, the Kennedy Space Center. Before the Kennedy Space Center (KSC) was built

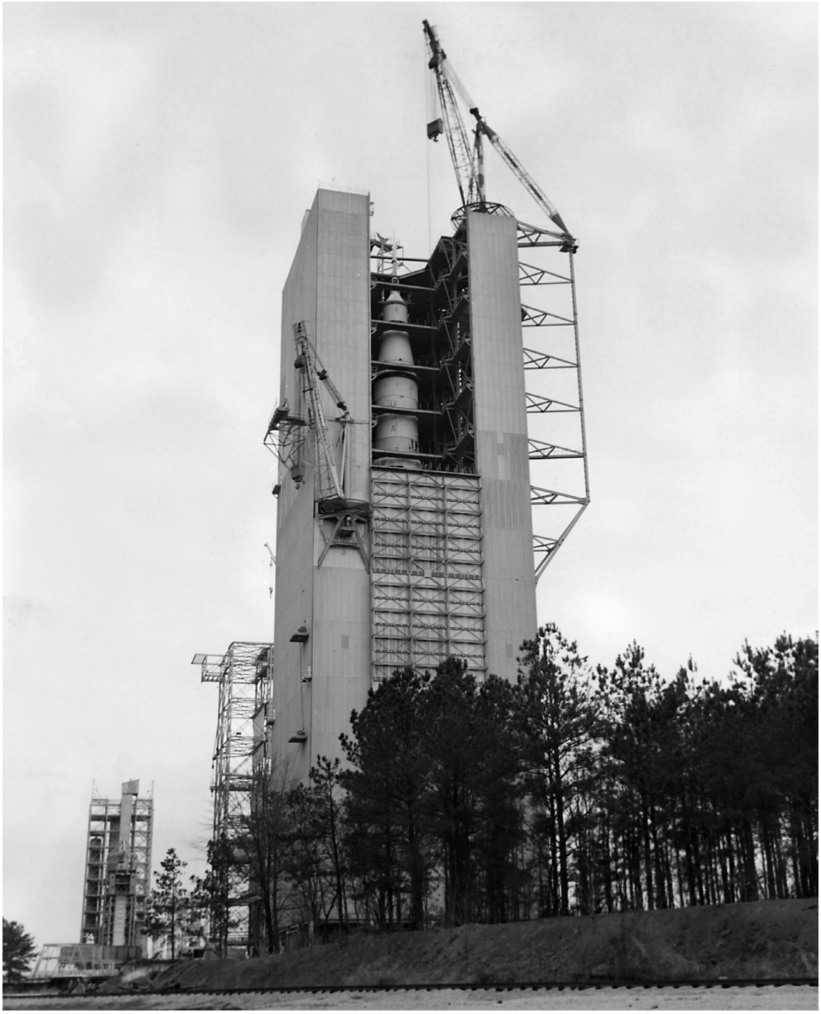

Figure 3.6. Saturn V Dynamic Test Vehicle assembled for Configuration I testing, 1966 (photo by Cooper, U.S. Space and Rocket Archives file SA-500D, courtesy of NASA).

Figure 3.7. Cape Canaveral in the 1960s, looking north along Missile Row, with the Vehicle Assembly Building (VAB) under construction in the upper left corner (photo courtesy of NASA/U.S. Army).

Figure 3.8. The Bumper 8 was the first missile launch at Cape Canaveral, occurring on July 24, 1950 (photo courtesy of NASA/U.S. Army).

in 1962–63, CCAFS had already achieved many important milestones in space history, including the launch of Explorer 1 in 1958 at Launch Complex 26A and later in support of the Mercury and Gemini programs. The first manned test for Alan Shepard's May 5, 1961, suborbital flight used the Redstone booster (figure 3.9), as mentioned previously, and the first American in orbit, John Glenn, was launched by the larger Atlas D rocket on February 20, 1962, at the site (NASA 2008a).

Although best known for its rocket launching for manned and unmanned missions, CCAFS was also home to dozens of smaller test rocket launch pads, many of which have been abandoned and now lie in disrepair. As recently as 2014, visitors on KSC's historic tours of Cape Canaveral launch pads and testing facilities (the Up Close Cape Canaveral: Then and Now Tour) were unable to visit many of the historic pads, a restriction attributed to deteriorating road and ground conditions from neglect that present human and vehicular safety hazards. In May 2015, the tour was suspended over national security concerns, and the current state of integrity of many historic launching facilities is unknown by the broader historic preservation community.

As the U.S. space program advanced and the Apollo program began to develop, land adjacent to CCAFS was acquired and converted into the Kennedy Space Center. In 1958, NASA's launch operation was originally known as the Launch Operations Directorate (LoD) and reported to the Marshall Space Flight Center in Alabama. The LoD consisted of a few buildings in the Industrial Area of the Cape Canaveral Missile Test Annex (at CCAFS), but the accelerated goal of a lunar landing by 1969 required an expansion of launch operations to Merritt Island. NASA began its land acquisition in 1962, buying title to 131 square miles and negotiating with the State of Florida for 87 more square miles (Benson and Faherty 1978). Architect Charles Luckman designed the major buildings in KSC's Industrial Area (Muschamp 1999). On July 1, 1962, the site was named the Launch Operations Center, achieving equal status with other NASA centers; and on November 29, 1963, the facility was given its current name by President Lyndon B. Johnson under Executive Order 11129 following Kennedy's death.

Human missions to the Moon required the enormous three-stage Saturn V rocket, which meant the construction of a new launch

Figure 3.9. Mercury-Redstone 3 Freedom 7 lifted off from Cape Canaveral on May 5, 1961, as the first U.S. manned launch, with Alan B. Shepard Jr. aboard (photo courtesy of NASA).

complex. Construction on Launch Complex 39 (LC-39) on Merritt Island began in November 1962.

LC-39 pads A and B were completed by October 1965 (figure 3.10), the Vehicle Assembly Building (VAB) was completed in June 1965, and the infrastructure was finished by late 1966. The complex included a hangar capable of holding four Saturn Vs; the VAB; a transporter capable of carrying 5,440 tons; and a 446-foot mobile service structure. Three mobile launcher platforms were also built.

Between 1967 and 1973, thirteen Saturn V launches occurred at LC-39, including the ten remaining Apollo missions after Apollo 7. Apollo 4 was the first of three unmanned flights and on November 9, 1967, was also the first rocket launch from KSC itself (figure 3.11). The Saturn V's first manned launch on December 21, 1968, was Apollo 8's lunar orbiting mission. The lunar module was tested by the next two missions: Apollo 9 (Earth orbit) and Apollo 10 (lunar orbit). Apollo 11 launched on July 16, 1969 (figure 3.12), and made the first Moon landing on July

Figure 3.10. The Apollo-Saturn 506 with Apollo 11 spacecraft being moved from the Vehicle Assembly Building to Launch Complex 39A on May 20, 1969 (photo courtesy of NASA).

Figure 3.11. Apollo 4 launch, Cape Canaveral, November 9, 1967 (photo 1967-113A, courtesy of NASA).

20. Apollo 12 followed four months later. Other launches from LC-39 were Apollo 13 on April 11, 1970; Apollo 14 on January 31, 1971; Apollo 15 on July 26, 1971; and Apollo 16 on April 16, 1972.

In 1972, after the launches of the Apollo vehicles, the Apollo program concluded at KSC with its last mission, Apollo 17. On May 14, 1973, the last Saturn V launch put the Skylab space station in orbit. Pad B, modified for Saturn IBs, was used to launch three manned missions

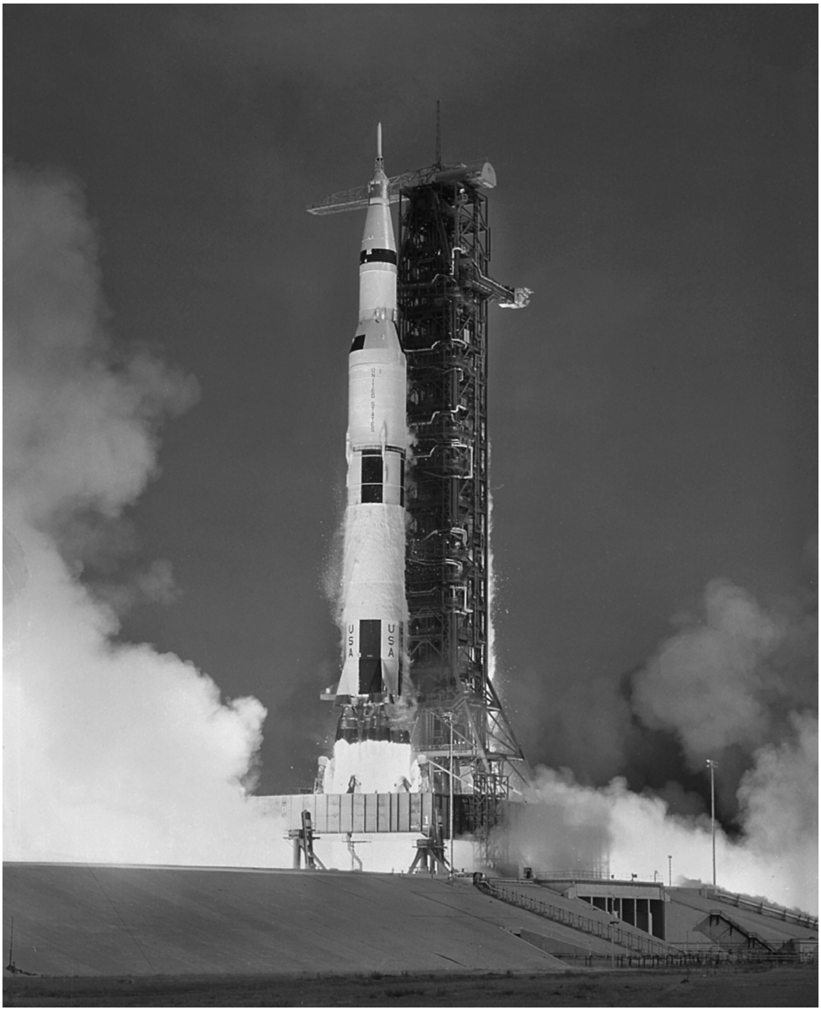

Figure 3.12. Apollo 11 launch from Launch Complex 39A, 1969 (photo courtesy of NASA).

to Skylab that year, as well as the final Apollo spacecraft for the Apollo-Soyuz Test Project in 1975.

During the late 1970s, LC-39 was reconfigured to accommodate the larger and heavier space shuttle (figure 3.13), including support structures like three orbiter processing facilities. Recently, the complex was further modified for commercial space travel and no longer appears to retain the integrity of the Apollo era. A comparison of figures 3.12 and

Figure 3.13. Launch of *Discovery* (STS-128) in 2009 for the last nighttime launch, at Launch Complex 39A, showing the much larger superstructure compared to that of the Apollo era (photo provided by M. W. Donaldson).

Figure 3.14. Edwards Air Force Base Research Lab (photo courtesy of Edwards AFB).

3.13 illustrates the modifications that have been made since the Apollo program. Despite the changes, LC-39 remains listed on the National Register of Historic Places (NRHP).

If there is one counterpart to Cape Canaveral in the West, it is Edwards Air Force Base (AFB). Formerly Muroc Air Force Base, it is situated in the Mojave Desert in southern California, approximately 22 miles northeast of Lancaster. Its inception in the late 1940s was precipitated by a concern that ongoing flight tests of large volumes and top secret aircraft at Wright Field in Ohio in 1942 would lead to breaches of security, which compelled officials to find an isolated site “away from prying eyes.” The site dictated a location with good year-round flying weather and a spacious landing field. Several locations were investigated throughout the country before the enormous flat surface of Rogers Dry Lake, close to a training base at Muroc, California, was selected (figure 3.14).

The earlier acceleration and deceleration experiments, beginning during World War II and using rocket sleds, were made by Lieutenant Colonel John Stapp, who also experimented with early high-altitude

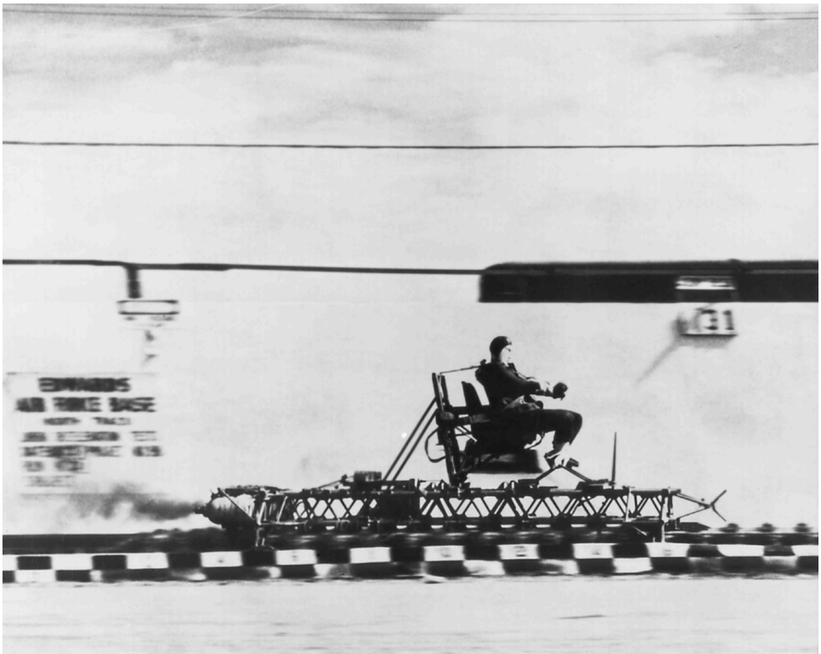

Figure 3.15. Lieutenant Colonel John Stapp on the rocket sled Gee Whiz at Edwards Air Force Base in 1944 (photo courtesy of U.S. Air Force).

flights, experiencing decompression sickness at the Wright Air Development Center at Wright Field. His first experiments were with nonhuman primates, and he later, in 1944, subjected himself to the 2,000-foot sled track on a rocket sled called the Gee Whiz (figures 3.15 and 3.16) at Rogers Dry Lake, Edwards AFB.

Colonel Stapp also participated in windblast experiments and one of the first high-altitude skydives, later working with Joseph Kittinger over the Tularosa Basin in New Mexico. Colonel Stapp was one of the most important individuals to put his life on the line to test human tolerance of abrupt acceleration and deceleration for the space program.

Among the other activities at Edwards AFB was the testing of high-thrust missile rocket engines in 1946—a need identified by the Power Plant Laboratory at Wright-Patterson Air Force Base. The facility needed to be government owned to allow for high-thrust missile rocket testing by different manufacturers. The location chosen was the remote

Leuhman Ridge, east of Rogers Dry Lake on Edwards AFB, which would later become the Experimental Rocket Engine Test Station.

Edwards AFB's role in space history did not end with Apollo, however. After President Nixon announced the Space Shuttle program on January 5, 1972, Edwards AFB was chosen for space shuttle orbiter testing. The prototype space shuttle *Enterprise* was carried to altitude by the shuttle carrier aircraft (SCA) and released. In all, thirteen test flights were conducted with the *Enterprise* and the SCA to determine their flight characteristics and handling. On April 12, 1981, the space shuttle *Columbia* became the first shuttle launched into orbit, and it landed at Edwards AFB. The air base's immense lakebeds and its proximity to Plant 42, where the shuttle was serviced before relaunch, were important factors in its selection. It served as the primary landing area for the space shuttle until 1991.

After that time, NASA preferred Kennedy Space Center in Florida to save the considerable cost of transporting the shuttle from California to Florida. Edwards AFB and White Sands Space Harbor (formerly

Figure 3.16. The 2,000-foot sled track in situ at Edwards Air Force Base in 2015 (photo provided by M. W. Donaldson).

known as Northrup Strip) continued to serve as backups for the duration of the Space Shuttle program. Shuttles landed at Edwards AFB as recently as September 11, 2009, because of rain and ceiling events at the KSC Shuttle Landing Facility. There was one space shuttle orbiter landing at White Sands Space Harbor in 1982. STS-126 was the only mission to land on temporary runway 04 at Edwards AFB, as the refurbished main runway was operational from STS-119 through the retirement of the shuttles. Beginning on April 12, 1981, shuttle mission STS-1 with the orbiter *Columbia* was the first flight of the program. The last shuttle mission, STS-135, flown by *Atlantis,* was in July 2011.

Although its long and broad space history can be only briefly addressed, Edwards AFB presents an excellent opportunity for historic preservation on a diachronic and landscape level and can serve as an example of a well-thought-out plan for evaluating space sites. A more complete discussion of U.S. historic preservation laws and regulations, within which such plans must occur, is presented later in this book. In the *Historic Context Statement Report for Evaluation of Cold War Era Properties on Edwards Air Force Base, California,* SWCA Consultants (2012) presents a well-defined plan to adequately identify historic districts on Edwards AFB. The context statement also defines systematic methods to differentiate between properties that are eligible or ineligible for listing on the NRHP. Rather than assessing buildings in contextual isolation, the study advocates for the implementation of cultural resource management strategies that focus on evaluating and protecting potential historic districts, which recognizes the spatial and contextual relationship between multiple features and structures. Such programs can be used as a model for other similar complexes and facilities, even those that lack the stature and size of Edwards AFB.

The Santa Susana Field Laboratory (SSFL) was established after World War II to test engines for missiles, spacecraft, and rockets in the Simi Valley, north of Van Nuys, California. The selection and design of the site by Rockwell was influenced by the German World War II test program, wherein V-2 rocket testing was done at abandoned rock quarries in Germany. Santa Susana's natural bowl area and canyons resembled the German quarries where von Braun and his team had worked.

Figure 3.17. Engine Hot Fire Test on Alfa Test Stand at Santa Susana Field Laboratory, 1960 (photo courtesy of NASA).

Construction began in 1947, and the SSFL location was used by several private companies and federal agencies. The first was Rocketdyne, originally a division of North American Aviation (NAA), which developed a variety of reliable liquid rocket engines. The Atomics International division of NAA built and operated the first commercial nuclear power plant in the United States, for the testing and development of compact nuclear reactors. Their work led to the first and only known nuclear reactor launched into low earth orbit by the United States, the SNAP-10A (NASA 2010a).

Beginning in the mid-1950s, the Alfa test site supported rocket engine static testing, including the Atlas, Navaho, Jupiter, and Thor engines, some of the earliest rocket testing in the program. These tests provided pivotal data for the development and improvement of many weapons and space vehicle booster systems. The testing facilities, Alfa Test Stands II and III (figure 3.17), remain in remarkably good condition

Figure 3.18. Alfa Test Stands II and III, Santa Susana Field Laboratory, 2008 (photo provided by M. W. Donaldson).

as of 2008 (figure 3.18). "Although Alfa III has undergone minor alterations over its lifetime, these changes have reflected new technologies and the requirements for testing different engines. Therefore, Alfa III maintains its integrity of location, design, setting, materials, workmanship, feeling, and association" (Archaeological Consultants Inc. and Weitze Research 2009: 5-1). The Alfa Test Area Historic District is also considered eligible for inclusion on the NRHP for its design and engineering of the test site, which was done by the Los Angeles architectural and engineering firm of Daniel, Mann, Johnson and Mendenhall Inc. (DMJM) with German engineer Walter Riedel, a rocket engine expert who had worked with von Braun.

During 1955–56, the Bravo test site was constructed south of Alfa and CTL II (figure 3.19); it was the second cluster of static test stands operational at Santa Susana. The Bravo site test stands also supported testing of F-1 components, lunar module rocket engine assemblies, and Atlas and Delta RS-27 engines. "Although Bravo II has undergone minor alterations over its lifetime, these changes have reflected new

technologies and the requirements for testing different engines. Therefore, Bravo II maintains its integrity of location, design, setting, materials, workmanship, feeling, and association" (Archaeological Consultants Inc. and Weitze Research 2009: 5-2). The Bravo II Test Stand is in very good condition as of 2008 (figure 3.20).

The Coca Test Area Historic District, similar to Alfa and Bravo, is considered eligible because of the Apollo and Space Shuttle programs from the period of significance beginning in 1955, the date of its design, until 1988, which reflects the formal conclusion of testing for the Space Shuttle program (figure 3.21). "Because it has achieved exceptional importance within the past 50 years, Criteria Consideration G applies. Under Criterion A, the Coca Test Area Historic District is considered eligible for its underlying associations with multiple static engine tests run between 1956 and 1988, beginning with tests of Atlas and Navaho engines in the late 1950s; the J-2 engine in the 1960s in support of Saturn/Apollo; and the Service Science, Management and Engineering in

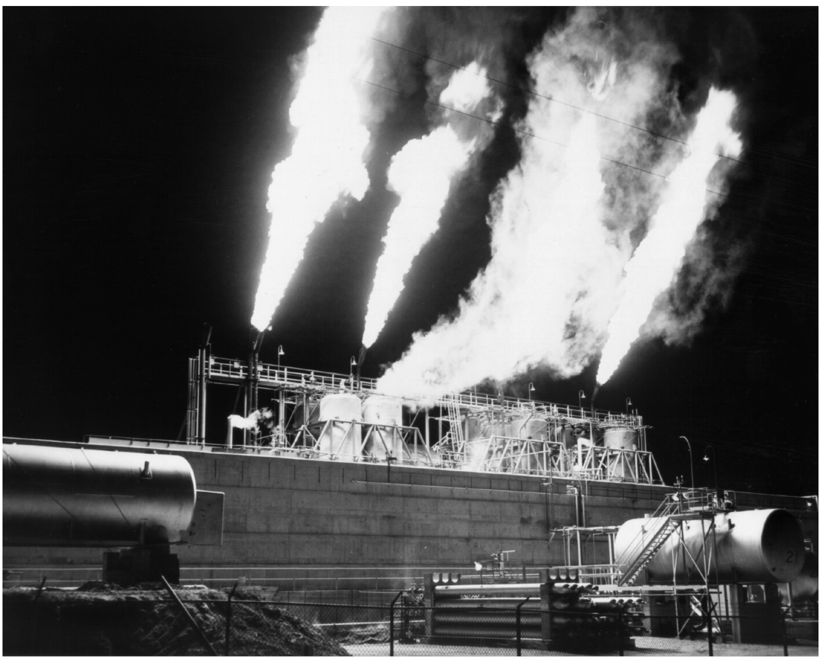

Figure 3.19. Component Test Laboratory II, Turbopump Test Facility, in NASA Area II, Santa Susana Field Laboratory, 1960 (photo courtesy of NASA).

Figure 3.20. Bravo II Test Stand, Santa Susana Field Laboratory, 2008 (photo provided by M. W. Donaldson).

the 1970s and 1980s in support of the Space Shuttle Program" (Archaeological Consultants Inc. and Weitze Research 2009: 5-2). The criteria listed above refer to the criteria for placing a property on the NRHP and are discussed in more detail later in this book.

Like the Alfa and Bravo test areas, the Coca Test Area Historic District is also significant under Criterion C for the design and engineering of the test site by DMJM, as well as rocket expert Walter Riedel. The Coca IV Test Stand maintains a high degree of structural integrity as of 2008 (figure 3.22).

Figure 3.21. Coca I Test Stand, J-2 Five Engine Cluster Hot Fire testing at Santa Susana Field Laboratory, 1965 (photo courtesy of NASA).

Figure 3.22. Coca IV Test Stand, Santa Susana Field Laboratory, 2008 (photo provided by M. W. Donaldson).

The Santa Susana Field Laboratory includes sites identified as historic by the American Institute of Aeronautics and Astronautics and by the American Nuclear Society (NASA 2010b).

Under an administrative order on consent with California's Department of Toxic Substances Control (DTSC), NASA has been tasked with

Figure 3.23. Mauna Kea Observatories, Hawaii, in 2013 (photo provided by M. W. Donaldson).

cleanup of toxic materials at the Santa Susana Field Laboratory to a "background level" that far exceeds other, similar mandated cleanups. This means that NASA will have to remove contaminated soil, in some places to a depth of 30 feet, and replace it with dirt brought in from outside California. NASA is in discussions with the State of California about the facility and the exact levels of remediation necessary. Cleanup to this high standard could mean several archaeological sites would be affected if the underlying soil were found to be contaminated. NASA proposes to demolish the Coca historic district in its entirety because this historic district has the largest test stands at the Santa Susana Field Laboratory, as well as the most extensive contamination, and is closest to the core of a Native American site declared to be sacred by the Santa Ynez Band of Chumash Indians, a consulting party.

Space sites occur in many locations in the United States. Farther west is another facility, situated at Mauna Kea in Hawaii (figure 3.23). At 13,796 feet (4,205 meters) above sea level, the summit of Mauna Kea on the Big Island, Hawaii, is home to the greatest collection of large

astronomical telescopes on the planet. Gerard Kuiper, after studying photos for NASA's Apollo program, began seeking an arid site for infrared studies. After looking at several locations, Kuiper began testing on Mauna Kea, and upon finding that his infrared testing was successful, he contacted NASA for funding to build a larger and more powerful telescope. NASA decided to hold an open competition and awarded the contract to John Jefferies and the University of Hawaiʻi. The project was finished in 1970. The Mauna Kea Science Reserve has thirteen observation facilities, each funded by as many as eleven countries.

As with the Santa Susana Field Laboratory, however, there was some opposition to later building there, because its designation by the Kanaka Oiwi as a sacred site has led to public protests, especially by Kahea, a Native Hawaiian organization, throughout Hawaii. The land is protected by the National Historic Preservation Act (NHPA) by the requirement to comply with Section 106 reviews because the site is significant to Hawaiian culture, but it is allowed to be developed. Earthjustice, a nonprofit public interest environmental law firm, maintains a regional office in Hawaii and has helped Native Hawaiian organizations protect sacred and cultural sites on Mauna Kea and in Oahu's Makua Valley (Kaufman 2009).

The Hawaiʻi State Supreme Court ruled in a fifty-eight-page opinion on December 2, 2015, to invalidate a construction permit for the $1.4 billion project in order to preserve Native Hawaiian culture and protect Mauna Kea, a mountain many consider sacred. The court ruled that the state's Board of Land and Natural Resources should not have issued a permit for the telescope before a hearings officer reviewed a petition challenging the project's approval (Kelleher 2015).

Another site in California is the Goldstone Deep Space Communications Complex (GDSCC), commonly called the Goldstone Observatory, located in California's Mojave Desert (figure 3.24). Operated by the International Telephone and Telegraph Corporation for the Jet Propulsion Laboratory, its main purpose is to track and communicate with space missions. It includes the Pioneer Deep Space Station, which is an NHL.

Constructed in 1958, the original Pioneer Deep Space Station was the first antenna to support the NASA's unmanned exploration of deep

Figure 3.24. Goldstone Deep Space Communications Complex, Mojave Desert, California, in 2010 (photo courtesy of NASA).

space, as well as the prototype antenna for the entire Deep Space Network for tracking deep space vehicles (NASA 2015h). The Pioneer Deep Space Station is scheduled to be dismantled, moved to a new site, and reassembled by the Barstow Community College Space and Technology Center, a Smithsonian Institution regional museum in California, as a visual centerpiece artifact on campus. Its status as an NHL will be removed, however, because its original location, setting, and site association with the GDSCC will no longer exist (Norwood 2010). As of 2016, the Pioneer Deep Space Station has not yet been moved.

Space Launch Complex 5 at Vandenberg Air Force Base in California was demolished in 2011 because of obsolescence. The Scout launcher there was salvaged for redevelopment at White Sands and redeployment to the Pacific Range. The complex was in use between 1961 and 1994, primarily to launch the Scout series of NASA-designed solid-fuel rockets that placed small research satellites into orbit. The Advisory Council on Historic Preservation did not participate in consultation at this complex to resolve adverse effects to the historic property by being demolished. A memorandum of agreement between Vandenberg

and the California state historic preservation officer called for the production of a Historic American Engineering Record (HAER) of the complex as a way to lessen the adverse effects of its dismantling and to retain information about the complex.

The Saturn S-II Historic District at the Naval Weapon Station at Seal Beach, California, is another facility. The U.S. Navy proposes to demolish buildings 112, 126, and 127 and to consolidate the operations in a newly constructed one-story building, the Strategic Systems Weapons Evaluation Test Lab. The existing buildings are deteriorating and unsuitable. The buildings in question are contributing to the NRHP-eligible NASA Saturn S-II Historic District, identified as eligible in 1999 in an inventory and evaluation of 178 Cold War–era properties at Seal Beach, in which 22 properties appear to meet the criteria for eligibility (Herbert and Freeman 2009). A contractor who performed the final assembly and testing of second-stage boosters for the Saturn V moon rocket used the buildings in the 1960s and early 1970s. The demolition will render the NASA Saturn S-II Historic District ineligible for NRHP listing. The undertaking includes eventual demolition of the remainder of all of the resources in the eligible district.

Many smaller and less-known rocket facilities are overlooked for their contributions to space heritage and preservation potential. One such example is the Keweenaw Rocket Range, an isolated launch pad located on Keweenaw Peninsula in Michigan. In operation between 1964 and 1971, the site was one of six similar launching facilities across North America that were used to launch solid-propellant Nike-Apache rockets as part of the International Geophysical Year (figure 3.25).

The purpose of the Keweenaw Rocket Range was to collect meteorological data that included electron density, positive ion composition and distribution, energetic electron precipitation, solar X-rays, and Lyman alpha flux. The joint effort by NASA and the University of Michigan was led by Harold Allen. Today, all that remains of the launch pad is a damaged plaque (figure 3.26).

The enormity of humankind's perennial interest in space and the American facilities built and all the components created through the decades that led to the Apollo program and landing humans on the Moon must not be minimized or marginalized. Artifacts on the Moon

Figure 3.25. Launch of Nike-Apache rocket from Keweenaw Rocket Range in January 1971 (photo courtesy of Roland Bruce Burgan, 1998).

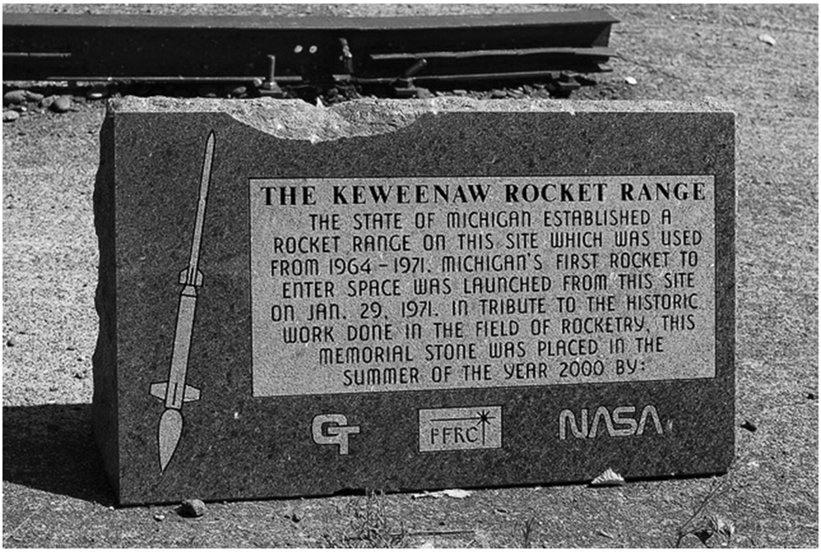

Figure 3.26. Monument at the remnant of the Keweenaw Rocket Range in 2012 (photo courtesy of James Tantalo, 2012).

are critical components to space heritage, but the places across the country that provided the research and the ability for those flights are the backbone of the historic story of America's space program. Their individual contributions, when considered together, demonstrate a huge impact on American rocket science, national security, and human ingenuity and should be considered for preservation.

4

Facilities to Protect Human Life and Safety

It is not unrealistic to acknowledge the contributions of scientists whose purpose was not to develop rocket engines but to invent new personal protective equipment that allowed astronauts to travel into space and back and survive. This elementary need has been downplayed in popular culture; the stuff of science fiction allows many events to happen that could not happen in real life. No one can actually be "beamed up," as in *Star Trek*. Likewise, "warp drive" in the same series was accompanied by a loud noise; however, there is no noise in space because space is, essentially, a vacuum. The real constraints presented by space flight have had repercussions for all the attempts to get humans into orbital flight.

The rockets that carried all the astronauts needed enormous power and several stages to reach space, yet even the definition of "space" is debatable. As Michelle Donegan (2009: 83) writes, "The question does not have a single agreed-upon answer." NASA (1958) defines space activities as "research into and the solution of problems of flight within and outside Earth's atmosphere." However, the end of Earth's atmosphere has no sharp boundary; instead, its density decreases with increasing altitude (Donegan 2009). The U.S. Air Force uses 80 kilometers in altitude for defining space, while NASA uses the altitude of 100 kilometers to determine who is an astronaut. Known as the Kármán line, this limit forms the boundary between aeronautics (airplanes) and astronautics (spacecraft). Donegan (2009: 84) describes this point as

where "the atmosphere becomes too thin to provide enough aerodynamic lift to support a vehicle's weight, so that a velocity faster than orbital velocity (and therefore significant thrust) is required in order to maintain that altitude. The trajectories of items below the Kármán line will degrade because of atmospheric drag and eventually crash."

The Kármán line was also used as a benchmark for commercial spaceflight by the Ansari XPrize, and SpaceShipOne was the first commercial spaceplane to reach it. SpaceShipOne was carried to a high altitude and then dropped by a plane; its rockets pushed it upward to achieve spaceflight in 2004 (Scaled Composites 2007).

Given the need to design for space environments of various definitions, researchers studied the effects of a wide range of nonterrestrial conditions on the many kinds of materials used both for spacecraft and on actual humans in space (Darrin 2015). Regardless of the definition used, the environment of space is very different from that of Earth, in many ways harsher. Often the evolution of the materials and design reflects the political and social history of the exploration of space as well as the scientific investigation (Darrin 2015).

In addition to the problems of getting a rocket into space, humans must survive in an environment that does not inherently support life as we know it on Earth. The human body is faced with many challenges in space, and trying to determine whether humans could take the strain of getting into space and remain there for any extended period of time took huge investments by NASA and other agencies. Thousands of experiments would affect decisions of how and when to actually send the first rockets with humans into space. While an exhaustive list of experimental studies and the technical evolution of the spacecraft cannot be given here, a discussion of a sample of the human studies and the current condition (if known) of their material correlates will provide insight into the historical contributions and historic preservation potential of this aspect of space heritage.

The effects of the acceleration as a spacecraft launches and enters space as well as when a spacecraft lands are experienced by the human body as g-forces. G-force is defined as the force acting on a body or object as a result of gravity or acceleration. It is measured in g's, where 1g is equal to the force of gravity at the Earth's surface, which is 9.8 meters

per second per second. G-forces are felt and measured on an object during its acceleration relative to free fall, such as during atmospheric reentry and during its launch acceleration into orbit.

We now know that launches by the space shuttle were relatively mild at 3g, whereas the Apollo astronauts experienced 9g at launch (Donegan 2009). However, during the early development of the human space flight program, these effects could only be estimated, not measured. Because astronaut safety was paramount and lack thereof would jeopardize the future of the space program, some of the earliest experiments in understanding the effects of this force focused on astronaut safety. These studies were carried out at facilities all over the county, including New Mexico.

Holloman Air Force Base (AFB) in Alamogordo, New Mexico, was established in 1942 as a World War II bomber crew training base, and in 1947 it became an air development center supporting numerous missile and space biology research programs. Part of its mission was for U.S. Air Force aeromedical research and experiments on the human constraints for space travel. Tests were conducted both on the ground and in the air. One facility at Holloman AFB was the 10-mile-long High Speed Test Track, which was used to test acceleration and deceleration forces measured in multiples of the force of gravity (g-force) (figures 4.1 and 4.2).

For humans to get to space, many experiments had to first be done on land. Rocket sleds essentially consist of a test platform propelled by rockets that slides along a set of rails. They were first used by the Germans near the close of World War II and by the United States early in the Cold War. In the years after World War II, airplanes were beginning to fly faster because of more powerful jet and rocket engines, but pilots were not getting more robust, and higher, faster flights meant more dangerous bailouts and crashes (Teitel 2014).

Studying human tolerances appealed to U.S. Air Force flight surgeon Colonel John Stapp. The g-force limit of human tolerance was unclear, therefore, the question of how pilots could be best protected needed to be determined. A rocket sled could accelerate the testing of equipment that was too dangerous or hazardous for testing directly by piloted aircraft. Testing ejection systems and technology using rocket sleds prior

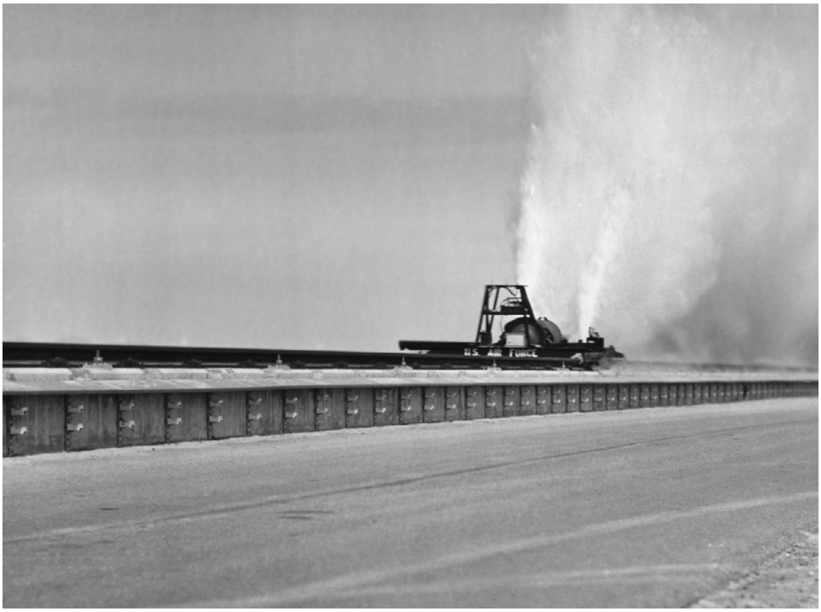

Figure 4.1. High Speed Test Track at Holloman Air Force Base, February 1959 (photo courtesy of Air Force Missile Development Center and the Emily Lovell Collection).

Figure 4.2. High Speed Test Track at Holloman Air Force Base in 2016 (photo courtesy of U.S. Air Force Senior Airman Aaron Montoya).

to their use in aircraft was an application at both Edwards Air Force Base and Holloman Air Force Base.

As mentioned earlier in the book, Colonel Stapp's first tests took place on the 2,000-foot-long track at Edwards Air Force Base in California. By 1951, seventy-four runs had been made by Stapp and others on the rocket sled there (Teitel 2014). One of the main reasons Stapp left Edwards was to ride on the longer, faster track with more violent decelerations at the High Speed Test Track at Holloman AFB in New Mexico. In cooperation with Northrup Corporation, a powerful rocket sled called Sonic Wind 1 was developed by Stapp and his team at Holloman AFB. The sled had a full propulsion section behind it and a water brake system at the end of the track. The underside of the sled had scoops attached that would dig into a series of dams between the rails and absorb the energy of the run and stop the sled (Teitel 2014).

On December 10, 1954, Colonel Stapp was strapped into an exact replica of a jet pilot's seat and rode a rocket-propelled sled along the High Speed Test Track at Holloman AFB (figure 4.3). In 5 seconds he reached a speed of 632 miles per hour, or Mach 0.9. It took just 1.4 seconds for the shed to come to a complete stop. The force of the stop was the same a driver would feel smashing into a brick wall at 120 miles per hour.

Colonel Stapp suffered injuries including several broken ribs and a temporarily detached retina. His sled run provided pivotal information

Figure 4.3. Colonel John Stapp on the High Speed Test Track at Holloman Air Force Base, 1954 (photo courtesy of U.S. Air Force).

on how gravitational stress affects a human body (Ika 2012). Stapp experienced 46.2g for several seconds. Generally, accelerations beyond 100g are lethal, even if momentary (GForces.net 2010). Colonel Stapp was called "the fastest man on Earth" (*Time* 1955).

The High Speed Test Track is currently operated by the 846th Test Squadron at Holloman AFB and has undergone modifications for different projects including the development of magnetic levitation capability to reduce vibration and accommodate larger payloads at higher speeds (Holloman AFB 2009). The original alignment has been maintained, and the same adjusting mechanisms that were used in the original track have been continued (Andrew R. Gomolak Jr., personal communication 2016) (figures 4.4 and 4.5). Several historic facilities, such as the three associated blockhouses, are no longer in use at the track. Overall, this site of important experiments in evaluating the human factors in space travel maintains its integrity and should be considered as a National Historic Engineering Landmark (Andrew R. Gomolak Jr., personal communication 2016).

Another track at Holloman AFB, named the Daisy Test Track and shorter than the High Speed Test Track, was designed and built by

Figure 4.4. Sonic Wind Sled replica at Holloman Air Force Base in 2016 (photo provided by B. O'Leary).

Figure 4.5. High Speed Test Track at Holloman Air Force Base in 2016 (photo courtesy of U.S. Air Force).

Stapp's team in 1955 (NASA 2015c). The track was designed for use by the AeroMedical Field Laboratory and was located immediately adjacent to the buildings of the laboratory complex. The Daisy Test Track allowed researchers to test a variety of different human body positions and the g-forces associated with them, providing a way to understand the impacts of space flight and which body positions allowed for the greatest likelihood of survival (O'Leary et al. 2010).

The track consisted of two rails 5 feet apart and 120 feet long. According to the original proposal from 1953 by Colonel Stapp, who was then head of the laboratory, propulsion was by compressed air catapult—hence the analogy with the popular Daisy air rifle and the use of that name for that track. Part of that track is now at the New Mexico Museum of Space History in Alamogordo (figure 4.6).

Another facility at Holloman AFB tested deceleration effects on humans. Known as the Bopper, it was a sled powered by large rubber bungee cords and propelled down a very short indoor track—either forward facing or rear facing—to a sudden stop (figure 4.7). The jolt felt by the test subject was measured and found to produce as much as 30g; duration, velocity rate, and electrocardiogram data were also collected.

Figure 4.6. Section of Daisy Test Track previously at Holloman Air Force Base and currently at the New Mexico Museum of Space History in 2016 (photo provided by B. O'Leary).

Figure 4.7. Restored Bopper sled on display at the New Mexico Museum of Space History, Alamogordo (photo by B. O'Leary).

One of the Mercury astronauts rode the Bopper in a pressurized space suit to see how the helmet impacted the cervical vertebrae (O'Leary et al. 2010). A restored Bopper sled is currently on display at the New Mexico Museum of Space History for its important role in research and development of the human spaceflight industry. The Bopper's data were reportedly utilized in early seatbelt and automotive design, as well.

The High Speed Test Track, the Daisy Test Track, and the Bopper were all used by the U.S. Air Force at Holloman AFB in Alamogordo, New Mexico. Meanwhile, NASA was carrying out other tests and research at another New Mexico facility, White Sands Test Facility (WSTF). WSTF was built in 1963 and 1964 as an extension of Johnson Space Center in Houston to provide laboratory facilities for testing the Apollo program propulsion system and materials used for the spacecraft. Originally named the Johnson Space Center Propulsion Systems Development Facility, it soon received a new name, White Sands Operations, and in June 1965 it received its final name, White Sands Test Facility. At the peak of the Apollo era, WSTF employed more than 1,700 people (NASA 2015d).

Even some of the most mundane materials were tested at WSTF, including the ink used to label all switches and lights inside the space capsule. The manufacturer had changed the ink formula to make it more readable, but the researchers at WSTF found that the ink gave off a significant amount of gas that, while not fatal, would cause irritation for the astronauts breathing it in (Eckles 2013).

Currently, WSTF employs 750 people, and despite a near closure in 1970, the facility remains operational today. It had expanded its facilities to accommodate the former Space Shuttle program, as well as the International Space Station and the Peacekeeper missile (NASA 2015d).

Well-known testing was carried out at nearby White Sands Missile Range (WSMR), a U.S. Army rocket range established in 1945 as White Sands Proving Ground. A critical test for the Apollo program performed at WSMR was for the Apollo launch escape system (LES). Jim Eckles (2013: 421) writes, "The LES consisted of a tower attached to the top of the crew capsule. Solid-propellant rocket motors were mounted on the tower which could be quickly fired in an emergency. The rockets

were designed to lift the capsule away from the main vehicle and boost it to the side and out of the way. Then parachutes were to be deployed for a soft landing back near the launch point."

A series of these tests was conducted between 1963 and 1966 at WSMR. Through the use of a rocket known as Little Joe 2, LES was subjected to unmanned tests to demonstrate the adequacy of the Apollo launch escape system and to verify the performance of the command module's Earth landing system (O'Leary et al. 2010). LES was tested under various conditions, before the booster rockets left the ground and during various stages of flight (Eckles 2013). They were conducted on WSMR at Launch Complex 36 (LC-36).

As with many test facilities built for space exploration, if the physical facilities were not abandoned they were frequently repurposed and their elements used for other launches and tests. Parts of Launch Complex 36 were still in use in 2015. The actual concrete pad where Little Joe was tested is still present. The blockhouse, albeit changed for subsequent missions, maintains a similar configuration in the interior (figures 4.8 and 4.9).

Building 23358, the vehicle assembly building at Launch Complex 36 (LC-36), was built in 1960; there the Little Joe rocket and payload integration were assembled before Little Joe 2 was brought to the launch area. Despite having undergone some modifications since initial construction, this structure still currently serves to assemble vehicles in NASA's Sounding Rockets program (figures 4.10 and 4.11).

Although modifications to the historic structure have since occurred, the original architectural elevation has been preserved in drawings of work as built (White Sands Missile Range Archives 2015). The VAB at LC-36 was inventoried by archaeologists in 1995, a New Mexico Historic Building Inventory form was completed, and the study determined the property eligible for inclusion in the National Register of Historic Places.

Subsequently, in 2009, a section of a 1982 addition to the VAB was demolished and replaced by a two-story structural upgrade to the facilities. This change received concurrence from the New Mexico state historic preservation officer in 2010 as having "no adverse effect" on the historic property (O'Leary et al. 2010). In essence, for this particular era

Figure 4.8. Interior of the blockhouse at Launch Complex 36 at White Sands Missile Range, circa 1960s or 1970s (photo courtesy of John Young, White Sands Missile Range).

Figure 4.9. Interior of the blockhouse at Launch Complex 36 at White Sands Missile Range in 2015 (photo provided by B. O'Leary).

Figure 4.10. Vehicle Assembly Building at Launch Complex 36 at White Sands Missile Range, circa 1970–81 (photo courtesy of White Sands Missile Range).

Figure 4.11. Vehicle Assembly Building at Launch Complex 36 at White Sands Missile Range in 2015, view west (photo provided by B. O'Leary).

of space heritage at WSMR, much of the original character and architecture of the facilities has been preserved and still convey the historical significance of Little Joe 2 and its contribution to space heritage.

Testing of the equipment, human life support, and escape systems was not enough to allow for human spaceflight. Until it could be demonstrated that animals, and in particular, dogs and primates, could withstand actual spaceflight under the conditions simulated by tests on Earth, human spaceflight was not possible. In fact, the first animals to enter space were mammals, and some of the most important animal research was carried out in facilities in New Mexico and other parts of the world.

As was the case with the first successful orbit of Earth, the Soviets were the first to test animals in orbit. In 1958, Sputnik 2 carried a stray dog from Moscow named Laika. Although Laika died within hours from overheating, she survived long enough to show that mammals, under certain conditions, could survive. By the time Sputnik 5 launched in 1960, its crew of two dogs (named Strelka and Belka) demonstrated that mammals could survive the entire launch, the orbit of Earth eighteen times, and reentry of the capsule. Both dogs were recovered, unharmed, marking the first time living specimens had been recovered from orbit (McNamara 2001: 56).

Because the Soviets were already ahead in launching dogs into space, the United States needed to dial up the testing of life support systems in its capsules to get more data on the effects of space on humans and their ability to perform mission-critical duties under all foreseeable circumstances, including emergencies. At the beginning of the space program, chances were high that astronauts would be killed if something failed or in the event that the heat shield on the capsule that held the astronauts during reentry was not able to withstand high temperatures. The physical stresses that humans were facing were becoming clearer and seemed insurmountable at the time. The first "Big Joe" test, which was the start of Project Mercury in 1959, recorded speeds of the capsule after it separated from the rocket at 15,000 miles per hour and an external temperature of 3,500 degrees Fahrenheit on the heat shield of the capsule. The inside of the capsule needed to be at a temperature that was livable. Despite these design constraints, one of the least

reliable parts of the spacecraft was not actually the capsule but the Atlas launch rocket, estimated to be only 80 percent reliable (McNamara 2001). Such a high level of risk was unacceptable for manned space flight. It was critical that NASA improve the reliability of the launch rocket and develop safety measures that allowed the astronaut to eject in case of failure.

Some of the earliest in-flight tests using nonhuman primates began with a series of unmanned suborbital flights launched from Wallops Island, Virginia. These tests, referred to as "Little Joes," were done at both Wallops Island and WSMR in testing the launch escape systems and heat shields (McNamara 2001).

Before tests with humans were deemed safe, NASA selected its test subjects from species of nonhuman primates, which are our closest relatives. The first to be tested were monkeys, and later chimpanzees, with whom humans share 98 percent of our DNA. Using these animals in experiments and early rocket launches allowed researchers to conduct biological studies that called for a human response.

When the hardware and escape systems had been tested in unmanned capsules, the next step was to use a nonhuman primate, who was considered expendable. In 1959, rhesus monkeys (*Macaca mulatta*) were raised in San Antonio, Texas, at the Air Force School of Aviation for the sole purpose of being subjected to rocket launches. The first monkey was named SAM (an acronym for the U.S. Air Force School of Aviation Medicine at Brooks Air Force Base, Texas), and in his craft (Little Joe 2), he reached weightlessness for about 3 minutes at an altitude of 280,000 feet (figures 4.12 and 4.13). The escape system and heat shields worked, and SAM was unharmed when he was retrieved.

With testing of monkeys well under way, the Holloman Aerospace Medical Center at Holloman AFB began training the first chimpanzees for spaceflight (McNamara 2001). Genetically closest to humans, *Pan troglodytes* (the common chimpanzee) was believed to be a species that would more accurately predict the human response to spaceflight. The original group of chimpanzees was captured in the wild in Africa and then treated for any illnesses or medical issues before being subjected to research. Several of these primates were selected as part of Project Mercury to test the capsule's life support systems, under either

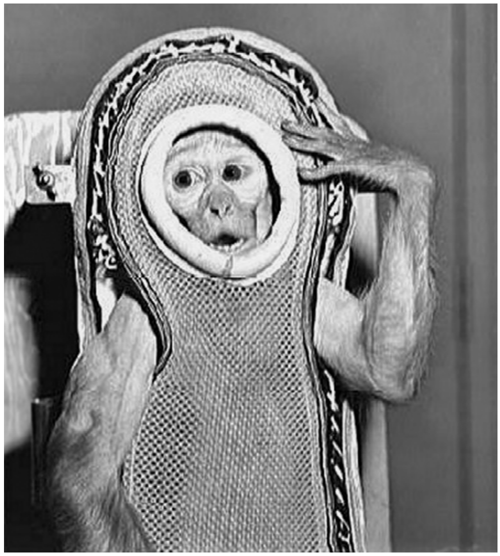

Figure 4.12. SAM before the flight on Little Joe 2 (photo courtesy of NASA).

Figure 4.13. Little Joe 2 launch in 1959 (photo courtesy of NASA).

simulated conditions or actual flight testing, such as the Mercury-Redstone 2 (MR-2) test.

The goal of the suborbital flight MR-2 was to carry a live chimpanzee, who was trained to respond to lights in the capsule during the space flight, to measure the animal's physical responses. This was believed to provide data on not only the medical effects of the g-forces and weightlessness but also the effects of the same on consciousness (McNamara 2001). One of several primates, called HAM (an acronym for Holloman Aerospace Medical Center), was selected from the Holloman Aerospace Medical Center to participate in launch exercises.

On January 31, 1961, HAM became the first chimpanzee to launch into space. With HAM on board, MR-2 blasted off from Cape Canaveral and reached a height of 157 miles and a speed of 5,860 miles per hour. HAM experienced a g-force of 14.7 and weightlessness for 6.6 minutes (McNamara 2001). Seventeen minutes later, HAM was rescued in good condition. After the flight, HAM lived for seventeen years at the National Zoo in Washington, D.C. After his death in 1983, HAM was returned to New Mexico and buried at the International Space Hall of Fame at the New Mexico Museum of Space History.

The use of mammals, including nonhuman primates, during testing and development, and the sacrifices they made, paved the way for human testing. Some of the most extraordinary early human test flights were part of Project MANHIGH, a U.S. Air Force balloon flight program designed to assess the effects of environmental conditions on humans in the stratosphere. The program sought to develop protocols to study humans and their physical reactions in space (Stratocat 2010). Several flights over WSMR tested capsule design and allowed for decision-making processes that would be largely inherited by Project Mercury and, later, by the Apollo program (Hamilton 1995).

Of particular importance was Project Excelsior, a series of high-altitude parachute jumps made by Colonel Joe Kittinger in 1959 and 1960. These jumps were made to test the parachute system and to solve high-altitude escape problems. In one of the jumps, Kittinger set, and still maintains, the longest drogue parachute free-fall record. At the time, Kittinger set the world record for the highest parachute jump and the fastest speed by a human through the atmosphere—a record

that was not broken until 2012 (by Felix Baumgartner). The problem that Project Excelsior sought to solve was how to provide astronauts with a safe method of escape while they were still in the atmosphere; without proper stabilization at high altitudes, a human would enter a deadly spin of almost 200 revolutions per minute (O'Leary et al. 2010). The parachute design being tested was multistaged and consisted of a second stabilizer parachute that would prevent uncontrolled tumbling or spinning. The "Beaupre Multi-Stage" parachute had a timing and altitude system that automatically deployed the stabilizing and main parachutes at the appropriate times during the free fall (National Museum of the Air Force 2010).

On August 16, 1960, Kittinger—outfitted in a pressurized suit that by today's standards would be considered archaic—jumped from an open gondola carried aloft by a balloon hovering 102,800 feet over the Tularosa Basin in New Mexico. He fell freely for 84,700 feet, reaching speeds of 614 miles per hour, exceeding the speed of sound (National Museum of the Air Force 2010). Thirteen minutes and 45 seconds later, he landed, unharmed, after his parachute system successfully deployed as designed.

Not surprisingly, not all of the hypotheses on the effects of spaceflight on humans could be directly tested, as was the case with Colonel Kittinger's historic jump. Some facilities were built to simulate, to the greatest extent possible, specific circumstances and the projected human reactions to the same.

The Neutral Buoyancy Space Simulator (figure 4.14) was designed by the U.S. Army in 1955 and used by NASA as a training facility to provide a simulated zero-gravity environment in which engineers, designers, and astronauts could perform for extended periods of time in the simulated environment of outer space (National Park Service 2001). It contributed significantly to many American manned space missions, including those of Gemini, Apollo, Skylab, and the space shuttle, and was the only test facility that allowed astronauts to become familiar with the dynamics of body motion under weightless conditions until the mid-1970s. The facility, as described by the National Park Service (2001) "consists of a tank, 75 feet in diameter and 40 feet deep [with] life support . . . simultaneously provided by monitoring systems for

Figure 4.14. Neutral Buoyancy Space Simulator (photo courtesy of NASA).

up to four pressure-suited subjects. Additional systems include data acquisition and recording, underwater lighting, special underwater pneumatic and electrical power operations of motor, valves, controls, and indicators that are required for high fidelity and functional engineering mockups and trainers."

Other research and development facilities tested (or continue to test) the effects of spaceflight on the spacecraft themselves, which, without structural integrity, would be devastating for their crews. In particular, wind tunnels were important places to observe the dynamics of aircraft design in test situations. The Unitary Plan Wind Tunnel at Moffett Field, near Sunnyvale in northern California, was one of the first to be used for the testing of spacecraft (figure 4.15). The predecessor to NASA, the National Advisory Committee for Aeronautics (NACA), developed this wind tunnel complex to serve the emerging need for supersonic research and development following World War II.

These tests include cruise performance, lateral and longitudinal stability, structural loads, and aeroelastic and dynamic load measurements (NASA 2015e, 2015f).

Construction began in 1950 as a result of the Unitary Wind Tunnel Plan Act of 1949 passed by Congress, and the first segment of the tunnel opened for operation in 1956. One of the tunnels built in the 1950s has a section in which aircraft models can be examined while their engines are running. The facility played a critical role in the U.S. space program, performing aerodynamic testing on the Mercury, Gemini, and Apollo spacecraft and the space shuttle (NASA 2015e). The wind tunnel was registered as a National Historic Landmark (NHL) in 1984.

Another wind tunnel at NASA's Ames Research Center at Moffett Field has been used to support an active research program in aerodynamics, dynamics, model noise, and full-scale aircraft and their components. The 40- by 80-foot circuit was originally constructed in the 1940s and is capable of providing test velocities up to 300 knots (350 miles per hour). The aerodynamic characteristics of new configurations are investigated with an emphasis on estimating the accuracy

Figure 4.15. Ames 16-foot High Speed Wind Tunnel (photo GPN-2000-001179, NACA A-12679, courtesy of NASA).

of computational methods. In addition to the normal data-gathering methods, state-of-the-art and nonintrusive instrumentation are available to help determine flow direction and velocity in and around the lifting surfaces of models or aircraft undergoing investigation. The 40– by 80-Foot Wind Tunnel is primarily used for determining the low- and medium-speed aerodynamic characteristics of high-performance aircraft, rotorcraft, and fixed-wing, powered-lift V/STOL aircraft (Butowsky 1984).

The 80- by 120-Foot Wind Tunnel at NASA's Ames Research Center is the largest wind tunnel test section in the world. This open-circuit leg was added and a new fan drive system was installed in the 1980s. The 80- by 120-foot test section is capable of testing a full-size Boeing 737 at velocities up to 100 knots (120 miles per hour). Although decommissioned by NASA in 2003, the National Full-Scale Aerodynamics Complex (NFAC) is now being operated by the U.S. Air Force as a satellite facility of the Arnold Engineering Development Center (AEDC).

"Save Hangar One" was the battle cry of a group of community leaders, citizens, and employees, past and present, who valued the former naval air station at Moffett Field. Hangar One's distinctive Streamline Moderne style is, without question, the most significant building, both architecturally and historically, to the Lighter-than-Air (LTA) naval military program of the 1930s. Designed by Karl Arnstein of the Goodyear Zeppelin Company and built in 1933, Hangar One is a contributing element to the United States Naval Air Station Sunnyvale Historic District.

When Hangar One was closed by the navy in 1994 as part of the Base Realignment and Closure Act, local citizens became concerned regarding its disposition, preservation, and reuse. NASA's Ames Research Center took possession of Hangar One in 2003, and the California state historic preservation officer (SHPO) became involved with the navy under Section 106 of the Comprehensive Environmental Response, Compensation, and Liability Act (commonly known as Superfund) involving the cleanup of a contaminant known as polychlorinated biphenyls (PCBs). PCBs were found in the 1930s siding panels and were the source of contamination in the Moffett stormwater settling basin. The structure was scheduled for demolition. The National Trust for

Historic Preservation finally listed Hangar One as one of their eleven most endangered historic places.

The SHPO requested that the Advisory Council on Historic Preservation (ACHP) conduct a tour of the site, meet with representatives of the navy and NASA, and conduct a public hearing. This review and deliberation was considered by a three-person ACHP panel to conclude the consultation process. The deliberation finally led to the adaptive reuse of Hangar One: "We urge the Navy, however, to focus its time and efforts to mitigate the adverse effects of its preferred removal action alternative on an enhanced collaboration with NASA to ensure the long-term survival and reuse of this historic property" (Donaldson 2008). NASA, in cooperation with Google and its subsidiary, Planetary Ventures, will be restoring Hangar One as well as running the airfield as a governmental low-use facility through a lease agreement.

On the other side of the country, Langley Research Center (LaRC) in Hampton, Virginia, is the oldest of NASA's field centers. It directly borders Langley Air Force Base. First established in 1917, LaRC focuses primarily on aeronautical research, though the Apollo lunar lander was flight-tested there, and several high-profile space missions have been planned and designed on-site. Originally established in 1917 by NASA's predecessor, NACA, the center currently devotes two-thirds of its programs to aeronautics and the rest to space. LaRC researchers use more than forty wind tunnels to study improved aircraft and spacecraft safety, performance, and efficiency. Between 1958 and 1963, when NASA started Project Mercury, LaRC served as the main office of the Space Task Group, until the office transferred to the Manned Spacecraft Center (now the Lyndon B. Johnson Space Center) in Houston in 1962–63.

Upon the start of Project Gemini, LaRC became a center for training for rendezvous in space. In 1965, LaRC opened the Lunar Landing Research Facility (LLRF). The issue at hand was that other than some marginal simulations using helicopters, which utilized a different propulsion mechanism, NASA needed a facility at which to develop and refine techniques for landing the lunar excursion module (LEM) on the Moon. When built in 1965, the LLRF included a mock Apollo LEM suspended from a 250-foot-high gantry over a simulated lunar landscape

Figure 4.16. Lunar Landing Research Facility at Langley Research Center, as photographed for the National Register of Historic Places (photo courtesy of National Park Service).

Figure 4.17. Neil Armstrong at the Lunar Landing Research Facility, 1970 (photo EL-1996-00192, courtesy of NASA).

that served to simulate the lunar gravity environment and full-scale LEM vehicle dynamics (figure 4.16). The gantry system used a lifting force by means of cables that effectively cancelled out all but one-sixth of Earth's gravitational force, similar to the conditions on the Moon. It was used by twenty-four astronauts, including Neil Armstrong (figure 4.17) and Buzz Aldrin (Langley Research Center 2015), to perfect landing techniques and maneuvering in low-gravity environments.

Langley's bold research and planning, led by John Houbolt, promoted the lunar-orbit rendezvous (LOR) concept. This experimental research initially began in 1959 at Langley but was not immediately embraced by NASA. The assembly included a command module, a LEM that could leave the Moon after landing, and a service module containing the main engine, fuel cells, and attitude control systems. This three-stage assembly was deemed necessary because a single rocket would likely have been unable to land on the Moon and return safely to Earth.

As the various components were developed, Langley led the way with its Rendezvous Docking Simulator to study the docking of the lunar module and the command module. The extravehicular activities program also gave astronauts training in walking, jumping, and running in the lunar-gravity simulator. The site has been listed as an NHL as part of the manned space flight programs.

Other facilities were designed with communication in mind. As discussed earlier, the Pioneer Deep Space Station, known as DSS-11 (figure 4.18), is a 26-meter polar-mounted antenna to support the United States' Pioneer 3 mission. The Pioneer program monitored some of the first NASA robotic voyages into deep space. This antenna became the prototype for the Deep Space Network and tracked many spacecraft, including Ranger, lunar orbiters, Surveyor, Viking, Voyager, Helios, and Apollo as well as the Echo Balloon projects. DSS-11 was no longer in use in 1981 and was made a National Historic Monument as the first deep space antenna in the U.S. network (National Park Service 1984).

The historic nature of America's space program does not end with a Moon landing or a docking with the space station. The teams and tools used to retrieve the aircraft once it splashes down or lands on a runway are an integral piece of the puzzle. After spending more than twenty-one hours on the lunar surface, the Apollo 11 Eagle blasted off for home.

Figure 4.18. Deep Space Station 14 at Goldstone Deep Space Communications Complex (photo courtesy of NASA/JPL–Caltech).

Once the lunar module had docked with *Columbia,* Apollo astronauts Armstrong and Aldrin transferred to the command module, and the lunar ascent module was jettisoned into lunar orbit. The Apollo 11 capsule splashed down in the Pacific Ocean on July 24, 1969, at 5:50 a.m. local time, after traveling more than 950,000 miles in a little more than eight days. The splashdown point was 920 miles southwest of Honolulu and 13 miles from the USS *Hornet* (Carmichael 2010).

The USS *Hornet* (CVS-12) was selected by the U.S. Navy as the prime recovery ship for America's first lunar landing mission. On July 24, 1969, President Richard Nixon, Admiral John S. McCain (commander in chief of the Pacific Command), and many other dignitaries were present while the USS *Hornet* recovered astronauts Neil Armstrong, Buzz Aldrin, and Michael Collins and their spacecraft.

Four months later, the USS *Hornet* repeated this flawless performance as the prime recovery ship for the recovery of Apollo 12, America's second lunar landing mission. On November 24, 1969, the Apollo 12 spacecraft Yankee Clipper, with its all-navy astronaut crew of Pete Conrad, Alan Bean, and Dick Gordon, splashed down a little over 2 miles from the aircraft carrier (figure 4.19).

At the time, scientists believed that the possibility of the astronauts bringing a dangerous Moon germ back to Earth was remote but not

impossible. The public perception bordered on panic. At this point in the recovery, the decontamination specialist, Lieutenant Clancy Hatleberg, jumped into the water from helicopter #66 and swam to one of the rafts. He donned a special biological isolation garment (known as a BIG suit) and then handed three other BIG suits into the spacecraft so the Apollo crews could put them on. These suits created an effective biological barrier for the astronauts who had come in contact with lunar dust so any germs could not spread to the recovery team (Carmichael 2010). Today, the USS *Hornet* is a floating museum, complete with the Airstream trailer where the astronauts were isolated onboard, docked in the San Francisco Bay.

Figure 4.19. Apollo 12 command module being hoisted aboard the USS *Hornet,* November 24, 1969 (photo S69-22185, courtesy of NASA).

These few examples of experiments and test facilities for allowing humans to survive in space pale before the thousands of tests in a myriad of places that happened worldwide and contributed to an understanding of how to get humans into space and onto a celestial body for the first time. The list of sites alone and the assemblage of objects historically involved is enormous; only a fraction have been recognized as historically significant by U.S. federal preservation authorities.

5

Astronaut Training Sites

By the time of Kennedy's speech in 1961, the United States was already deeply engaged in the Cold War space race with the Soviet Union. Kennedy's directive (and the funding that accompanied it) has long since been recognized as a major turning point in aerospace history—one that ignited support for the Apollo program and led to the famous first footsteps on the Moon at Tranquility Base on July 20, 1969.

NASA's primary challenge in meeting such an ambitious goal was to engineer a complex system of equipment and procedures that would ultimately be executed for the first time by astronauts in a high-risk, non-Earth environment. Toward that end, NASA quickly formed an ad hoc task group at the Office of Space Flight Programs, later named the Fleming Committee after chairman William Fleming, whose task was to carry out a study to determine the best approach and requirements for a manned lunar landing (NASA 1978). In just six weeks, Fleming's scoping study sought to identify all of the facets of the lunar landing missions, including spacecraft, launch vehicles, ground support, life and space sciences, and the recruiting and training of astronauts (Seamans 2005). Ironically, the final report, *A Feasible Approach for an Early Manned Lunar Landing,* noted that "very little study has gone into precisely what operations would take place on the Moon or how they would be executed" (Fleming 1961). In one sense, NASA accepted a blind challenge from President Kennedy, and the next eight years would test its resolve in preparing for one of the riskiest exploration missions in human history. Selecting the astronauts was only the first step.

Earlier, under the Project Mercury program, President Dwight D. Eisenhower decided that pilots from all branches of the military service would become the nation's first human voyagers into space. Because women were not selected—given the perception of danger of the missions and the widespread idea at the time that women did not have the physical abilities, experience, or skills to be chosen—the astronauts had to be first and foremost male test pilots. Each man was a talented specialist, excelled in piloting skills, and was in good physical and psychological health (NASA 2006).

According to NASA, "In seeking its first space pilots, NASA emphasized jet aircraft flight experience and engineering training, and it tailored physical stature requirements to the small cabin space available in the Mercury capsule then being designed. Basically, those 1959 requirements were: less than 40 years of age; less than 5 feet, 11 inches tall; excellent physical condition; Bachelor's degree or equivalent in engineering; qualified jet pilot; graduate of test pilot school, and at least 1,500 hours of flying time" (Kennedy Space Center [KSC] 2015; NASA 2006).

Over 500 service records were screened in January 1959 at the military personnel bureaus in Washington, and 473 pilots were finalized to be reviewed by the selection committee. Of these, 110 pilots were found to meet the minimum standards. This list of names included 5 Marines, 47 navy men, and 58 air force pilots. Several army pilots' records were screened earlier, but none was a graduate of a test pilot school. Although the final number of pilots to be selected as astronauts was 12, the enthusiasm to participate meant that several pilots would be carried along but not be able to participate in the flight program; a recommendation was made to reduce the number to 6 final astronauts (Reynolds 2013).

The assistant director of the Space Task Group, Charles J. Donlan, decided to divide the list of 110 arbitrarily into three groups and to issue invitations for the first group of 35 to come to Washington for briefings and interviews. The next week another group of possible pilot-candidates arrived in Washington. The high rate of volunteering made it unnecessary to extend the invitations to the third group, and a total of 32 pilots were selected and volunteered to continue. They

would be scheduled to undergo extreme mental and physical environmental tests at the Wright Air Development Center, in Dayton, Ohio, after being certified at Lovelace Clinic in Albuquerque, New Mexico, as physically qualified. The tests were to determine the best qualifications of each man, not necessarily to pick the best man.

For each pilot-candidate arriving at Lovelace Clinic, more than thirty different laboratory tests were performed for chemical, encephalographic, and cardiographic data collection. Each man's body was x-rayed and mapped. Almost everything about each candidate's eyes, ears, nose, and throat was chronicled. Special bicycle ergometer tests were performed, and determinations of total-body water volume, blood volume, and the specific gravity of the whole body were made, as were a total-body radiation count and complete cardiological examination. Even though each man had passed his yearly medical flight examinations, more-complete medical histories on these pilots helped narrow the field from 32 to 6. The candidates were so fit that only 1 of the 32 was found to have a serious enough condition to eliminate him from further tests at the Wright Aeromedical Laboratory.

Conducted at the Aeromedical Laboratory of the Wright Air Development Center, the selection program continued with an elaborate set of physical endurance tests, anthropometric measurements, and environmental and psychiatric studies. Pressure suit tests, acceleration tests, vibration tests, heat tests, and loud noise tests were conducted and monitored on each of the 31 candidates. In addition, each candidate tested his physical endurance on treadmills, walking on tilt-tables until his heartrate was 180 beats per minute. Each pilot also had to have his feet in ice water and blow up balloons until exhausted.

Candidates were also hassled with nonstop verbal interviews by psychologists and extensive self-examination using thirteen psychological tests for personality and motivation and asking the question "Who would you assign to the mission if you could not go yourself?" Being subjected to the human centrifuge experiencing eight times the weight of gravity, exposure to extreme heat, and experiencing the pressure of 60,000 feet in elevation were exhausting. From the 18 finalists, Donlan and his committee, in attempting to pare the selection down to 6, selected 7 pilots to become astronauts for Project Mercury.

On April 9, 1959, at a press conference in Washington, D.C., the 7 astronauts were introduced to the world: M. Scott Carpenter, 33; Donald K. Slayton, 35; L. Gordon Cooper Jr., 32; Alan B. Shepard Jr., 35; Walter M. Schirra, 36; John H. Glenn Jr., 38; and Virgil I. Grissom, 33. All became household names overnight. They were introduced in their civilian clothes and not in their uniforms representing the U.S. Navy, Marine Corps, and Air Force as an elite group of test pilots. They were all family men, average in build and looks, and engineers who were college educated and represented the hope of young men to follow them into space (Cortright 2009: 26).

President Eisenhower said, "The armed forces could have not won the war [World War II] alone. Scientists and businessmen contributed techniques and weapons which enable us to outwit and overwhelm the enemy." After the launch of Sputnik, Eisenhower promoted the integration of scientific programs with military efforts that would "draw into our planning for national security all the civilian resources which can contribute to the defense of the country" (Mieczkowski 2013: 53). Eisenhower knew the value of investing in the nation's public and private resources and the importance of not getting bogged down in technical areas that would impede progress.

By 1961, the only American human space flight had been Mercury astronaut Alan Shepard's fifteen-minute excursion in Freedom 7. NASA was not sure how the lunar challenge from President John F. Kennedy could be accomplished, but the staff of the agency knew they could not do it themselves. According to NASA (LaRC 2015), "Answering President Kennedy's challenge and landing men on the moon by 1969 required the most sudden burst of technological creativity, and the largest commitment of resources ($24 billion), ever made by any nation in peacetime." As Mercury phased into Gemini, and Apollo reached its peak effort, NASA's workforce grew to 390,000 men and women in industry, 33,000 in NASA centers, and 10,000 in universities. By 1969, the year of the first lunar landing, the total was 190,000. By 1974, it was down to 126,000 (Cortright 2009).

NASA also needed a wide range of private contractors. Some of the larger private firms to participate in the Apollo program were General Dynamics/Convair (Little Joe 2), General Electric, and the Glenn L.

Martin Company. Their primary missions were to study the feasibility of mission module separation from the command module, as well as redocking and propulsion systems. Grumman Aircraft Engineering Corporation received the contract for the design and construction of the lunar excursion module in Bethpage, New York. North American Aviation, Lockheed Propulsion Company, the Massachusetts Institute of Technology's Center for Space Research, the University of Cincinnati, the Carnegie Foundation, Columbia University, and Northern Arizona University were but a few of the organizations and universities involved in the Apollo project. Rice University donated land at Houston, Texas, to create the new Manned Spacecraft Center, which was renamed the Johnson Space Center by Congress in 1973. The Boeing companies (North American Aviation, Rockwell, and McDonnell Douglas) built and operated numerous facilities in California and Kansas and along the Gulf coast, where Saturn V and command and service modules were created, tested, and prepared for launch (Ron Anzalone, personal communication 2015). Critical to mission success were even the smallest efforts, such as those of the "backroom ladies" at International Latex Corporation (in a division later renamed ILC Dover) in Frederica, Delaware, who custom-made space pressure suits and their components, including hand-sealing the seams (Ron Anzalone, personal communication 2015; NASA 1994).

The Apollo program was one of the best governmental economic and work programs for the United States. Kennedy's administration in 1962 had estimated that the moon-landing project would cost $7 billion. This proved unrealistic, and the figure was reestimated to be $20 billion. In January 1969, NASA provided an itemized estimate of $23.9 billion to construct the fifteen Saturn V rockets, sixteen command service modules, and twelve lunar excursion modules, as well as program support, flight operations, tracking, and the upgrading of facilities. Claude LaFleur (2010) recently estimated that the Apollo program, dating from 1959 to 1973, had cost $20.4 billion. In 2010 dollars, that would be approximately $18 billion for each of the six landings, for a total of $108 billion.

The Apollo program showcased the public-private partnership and, in the race with the Soviet Union, illustrated how a single event of

landing a man on the Moon first promoted the United States' free-market system. Apollo's success required, however, tremendous organization and logistics, with thousands of institutions, private companies, and the public, operating within a vast governmental bureaucracy. After the selection of the astronauts, the next challenge was to train the men who would eventually reach the Moon.

Lunar missions were incredibly dangerous—not only because of the hazards of human space flight but also because no one knew how the lunar surface would react upon impact and with astronauts walking on it. Would the ground surface yield to the weight upon contact, engulfing the astronauts in its powdery surface? Cornell University professor Thomas Gold theorized that the continuous barrage of meteors had created both craters and fine dust, into which a lunar lander might sink into oblivion (Seamans 2005). Jerry Wiesner, chair of the Wiesner Committee on missiles and space, candidly informed President Kennedy in November 1962, "We don't know a damn thing about the surface of the Moon" (quoted in Seamans 2005).

A lack of information about the composition of the lunar surface also presented challenges for the other critical component of the Apollo 11 mission: to set up experiments and collect samples of lunar rocks and regolith. Analysis of these materials would guide future return visits and further scientific understanding of the lunar environment. An interesting paradox emerged: to design proper tools and collection equipment, one needed to understand the physical properties of the targeted materials, yet an understanding of such can be gained only from the collection of samples. As a result, NASA scientists embarked on research and development of special tools and equipment, like scoops and tongs, designed to work with the bulky and rigid Apollo space suits. For many of these specialized tools, only prototypes exist on Earth; several of these one-of-a-kind tools today remain discarded in an "artifact toss zone" on the lunar surface after use. Yet without data from the lunar surface, NASA's ability to design equipment and train astronauts to perform mission objectives on the Moon was hindered.

There were four primary areas of focus of training for astronauts. The first was basic life support: air to breathe, how to ensure proper pressurization, how much oxygen was needed, and how to carry out

basic bodily functions. The second was related to the stress of mission travel: how to withstand physical forces that can lead to a human blackout or cause death during a mission. These were problems solved by engineers and researchers at NASA facilities like Moffett Field and Dryden Flight Research Center in California and Holloman Air Force Base in New Mexico; flight-trained astronauts needed only to follow directions laid out in operating manuals that were carried on board.

The remaining two areas of astronaut preparation required more specialized training. The third relates to human movement in low- or zero-gravity environments, such as how to walk in spacesuits. The fourth pertains to the execution of mission objectives, like collecting rock samples, setting up experiments, operating equipment, and troubleshooting problems. This was particularly important, because in the early days of space flight, astronauts were expected to work with unreliable rockets and fly in a craft that was completely novel. Manufacturers had to build in redundancies that would allow the pilot to take alternative actions in case of a malfunction, and this required additional training (McNamara 2001).

Training in these areas needed to be conducted in similar environments and under similar circumstances to the Moon; complicating matters is that these behaviors had be done simultaneously to achieve the mission goals. However, at the time, humans had only seen the lunar environment from Earth, making the identification and replication of similar training environments problematic.

In 2009, the Lunar Reconnaissance Orbiter (LRO) provided NASA with high-definition imagery of the lunar surface (figure 5.1) taken from only 12 miles above the surface, dwarfing the grainy telescopic and satellite imagery from only a half century earlier (figure 5.2). Estimating the physical properties of the Moon using 1960s remote sensing technology was far more difficult without access to modern technology such as the LRO. Using only the data gained from telescopic and satellite imagery, NASA was tasked with identifying astronaut training locations on Earth that mirrored—as closely as possible—the conditions they expected on the Moon.

Credit for the application of remote sensing geological mapping of the lunar surface is shared primarily by two notable geologists. In 1960,

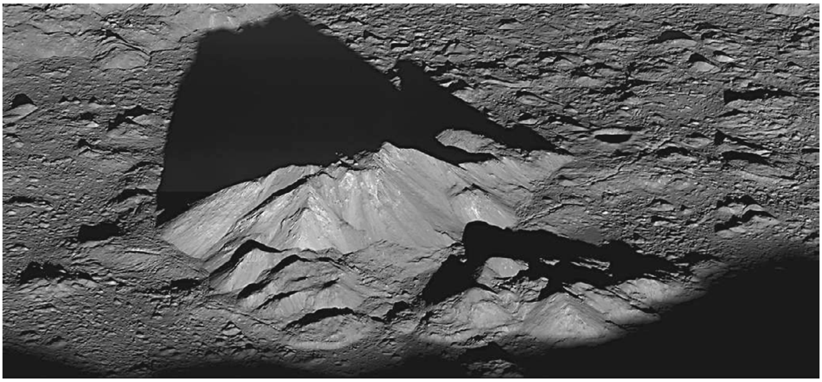

Figure 5.1. Tycho crater's central peak complex, as taken by the Lunar Reconnaissance Orbiter on June 10, 2011 (photo courtesy of NASA Goddard/Arizona State University).

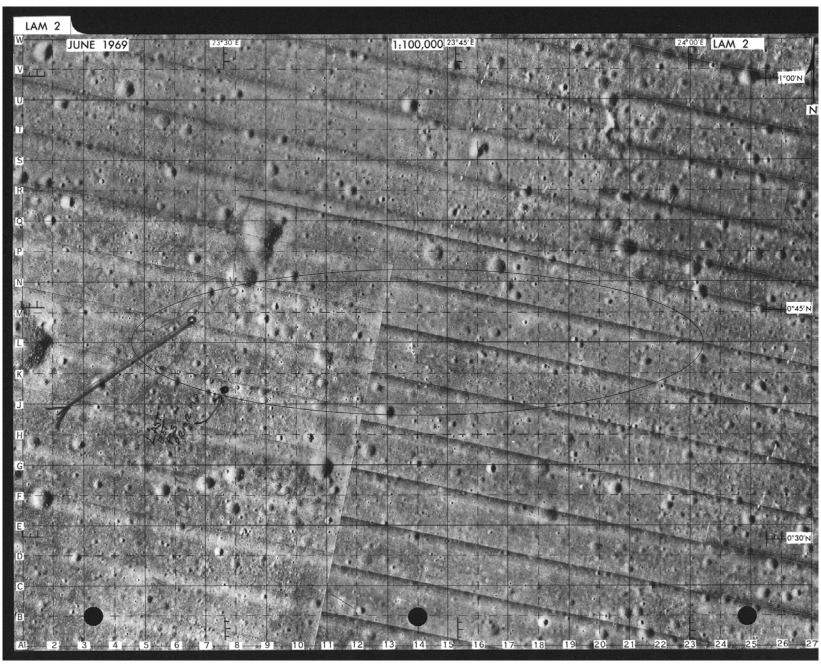

Figure 5.2. Map, circa 1969, used by Michael Collins to mark the estimated lunar module landing locations given to him by Houston (photo courtesy of NASA).

Arnold Caverly Mason (along with Robert J. Hackman) published the *Engineer Special Study of the Surface of the Moon*, under the direction of the Office of the Chief of Engineers by the Military Geology Branch of the U.S. Geological Survey (Mason and Hackman 1960). The study was based on a photogeologic analysis using stereoscopic vision of photographs of the Moon taken from McDonald Observatory in Fort Davis, Texas; Yerkes Observatory in Williams Bay, Wisconsin; Lick Observatory at Mount Hamilton, California; and Paris Observatory in Paris, France.

Mason concluded that the Moon is composed of the accretion of stony meteorites, breccia (rock that is composed of broken fragments of minerals or rock cemented together by a fine-grained matrix), and minor amounts of volcanic rock (primarily basalt). He further characterized the Lunar Highlands as comprising a "succession of contiguous, overlapping, and superimposed impact craters composed of unsorted, coarse, and partly blocky material" and interpreted the Lunar Lowlands as "relatively level plains with minor, low ridges, some rilles and escarpments, randomly scattered . . . craters, and some island-like highland areas. The surface of the lava is probably mostly smooth, but in part rough and clinker" (Mason and Hackman 1960). Mason's generalized photogeologic map has been cited as the first modern lunar geologic map based on stratigraphic principles (Wilhelms 1993).

The other pioneering geologist was Eugene Merle Shoemaker, who, while exploring for uranium deposits in Colorado and Utah in 1948, became introduced to the many volcanic features and an impact structure on the Colorado Plateau in the western United States: Hopi Buttes and Meteor Crater. It was between 1957 and 1960 that Shoemaker carried out his research on the structure and mechanics of meteorite impact and discovered coesite, a high-pressure form of silica created during impacts (Chapman 2015). Considered a pioneer in the new field of planetary impact science, Shoemaker is credited with applying geologic principles to the mapping of planets from telescope images (Chapman 2015) and was considered an authority in crater science. His involvement in the lunar Ranger missions led to his discovery that the Moon is covered with impact craters. To honor his contributions, some

of his cremains were flown with a lunar mission and are now located on the Moon (Jet Propulsion Laboratory 1998).

Through the work of Mason and Shoemaker, as well as countless NASA scientists and geologists, the lunar environment was characterized generally as a rough and rocky desert landscape, devoid of water and atmosphere. The logical step was to find locations on the Earth that mimic, as closely as possible, these projected environments and then train astronauts at those places to perform the scientific activities, geological identifications, and human functionalities required for the mission. In 1963, Shoemaker established the Astrogeology Research Center for the U.S. Geological Survey in Flagstaff, Arizona, in an area that would become one of the focal points of Apollo astronaut geological field training.

Because no single place on Earth possesses all of the requisite elements of lunar-like geology, Apollo astronauts traveled to thirteen states and five countries, including the United States, Germany, Iceland, Canada, and Mexico. Selected for their geological characteristics, remote landscapes, and in many cases, privacy, these training localities provided hands-on training in the identification of geological formations and rocks, sample collection, and documentation of the landscape that would be necessary on the Moon.

Most field visits were led by up to a dozen professional geologists and afforded mission astronauts (and, in some cases, their backups) education and training in critical mission activities. These locations are dominated by areas characterized as rocky desert landscapes or active volcanism because of their similarity to craters on the Moon. One of these training localities is Meteor Crater near Winslow, Arizona, located west of Flagstaff (figure 5.3).

Formed approximately 50,000 years ago by the impact from a nickel-iron meteorite 130 feet in diameter, Meteor Crater measures approximately 0.75 mile in diameter and is about 600 feet deep (Shoemaker 1987). According to Shoemaker, it is “one of the least eroded and best exposed impact craters in the world. Study of Meteor Crater provided clues for the recognition of impact craters on other solid bodies in the solar system, as well as on Earth, and stimulated the search for other terrestrial impact structures” (Shoemaker 1987: 399). Shoemaker’s rec-

Figure 5.3. Meteor Crater, Arizona, in 2010 (photo courtesy of Shane Torgerson).

ognition of the scientific value of Meteor Crater led to it being one of the most frequented astronaut training localities. During one training session, held on June 4 and 5, 1970, astronauts David R. Scott, James B. Irwin, Richard F. Gordon, and Jack Schmitt (who actually was a trained geologist) participated in a training with geologists. The training was composed of a flyover of Meteor Crater, followed by a pedestrian traverse around the rim and into the crater to observe the overturned flap, ejecta rays, shocked rocks, meteorite fragments, and ejecta blankets (NASA 2015i). Shoemaker was anecdotally known to have frequently lectured from the very edge of the crater (figure 5.4).

Another location, and a representative example of the training, was Sierra Blanca, Texas, near El Paso, selected because it is a volcanic center with a wide variety of volcanic rocks. According to Apollo 16 geology team leader Bill Muehlberger, the Sierra Blanca trip in 1969 was the only trip specifically on geology for the Apollo 11 crew (NASA n.d.).

At Sierra Blanca, Apollo 11 astronauts Neil Armstrong and Buzz Aldrin (figure 5.5), as well as Apollo 13 astronaut Jack Swigert and Apollo 17 astronaut Jack Schmitt, took part in training under the direction of geologists.

Figure 5.4. Dr. Eugene Shoemaker (pointing with hammer) lecturing to a group of astronauts at Meteor Crater, Arizona (photo courtesy of the Paul Switzer Collection, NAU.PH.426.476, Center of Astrogeology, USGS, Photo No. 56773, Cline Library Special Collections and Archives, Northern Arizona University, Flagstaff).

The training began with a two-hour walk-through with the geologists, who pointed out specific geological formations and explained what should be observed, how it should be described, and what should be sampled. This was followed by an exercise during which the astronauts were required to demonstrate their skills by performing numerous logistical and scientific exercises. They were required to locate themselves on an aerial photograph and then sample—using hand tools, sample bags, and maps—a suite of representative rocks from an arroyo to learn how to sample rocks when a variety are spread out (NASA n.d.). They were then required to document and describe—using

cameras, tape recorders, and VOX microphones—the geology of the area and the samples they collected and were expected to infer how the samples might be related to the observed volcanic stratigraphy in the surrounding Quitman Mountains. According to NASA researcher Ed Hengeveld, the recorders would capture any descriptions they made of the samples, and after the session, the descriptions could be discussed with the experts. Toward the end of the training, the investigation area was "salted" by the geologists with a few different rocks that had not been seen on earlier exercises to test the astronauts' ability to identify rocks out of context and hone their observational skills.

Also present during the training that day were Fred Haise and Jim Lovell (figures 5.6 and 5.7), who were Apollo 11 backup crew members and, later, two of the three Apollo 13 crew members. Sample collection tools used during the training session, including the scoops and tongs, were nearly identical to those to be used during the actual lunar missions.

Other training locations were considered valuable by providing similar topography to that of the Moon. One such example was Schooner

Figure 5.5. Astronauts Neil Armstrong (*left*) and Buzz Aldrin (*right*) document a sample during a geology training exercise at Sierra Blanca in West Texas on February 24, 1969 (photo S69-25908, courtesy of NASA).

Figure 5.6. Astronauts Fred Haise (*left*), holding collection tongs and wearing a tape recorder, and Jim Lovell (*right*), holding a scoop and a clear Teflon weigh bag on his hip, during the Sierra Blanca geology field training exercise on February 24, 1969 (photo S69-25902, courtesy of NASA).

Figure 5.7. Astronaut Jim Lovell (*left*) looking on and holding a Hasselblad camera while astronaut Fred Haise (*right*) examines a sample during the Sierra Blanca geology field training exercise on February 24, 1969 (photo S69-25199, courtesy of NASA).

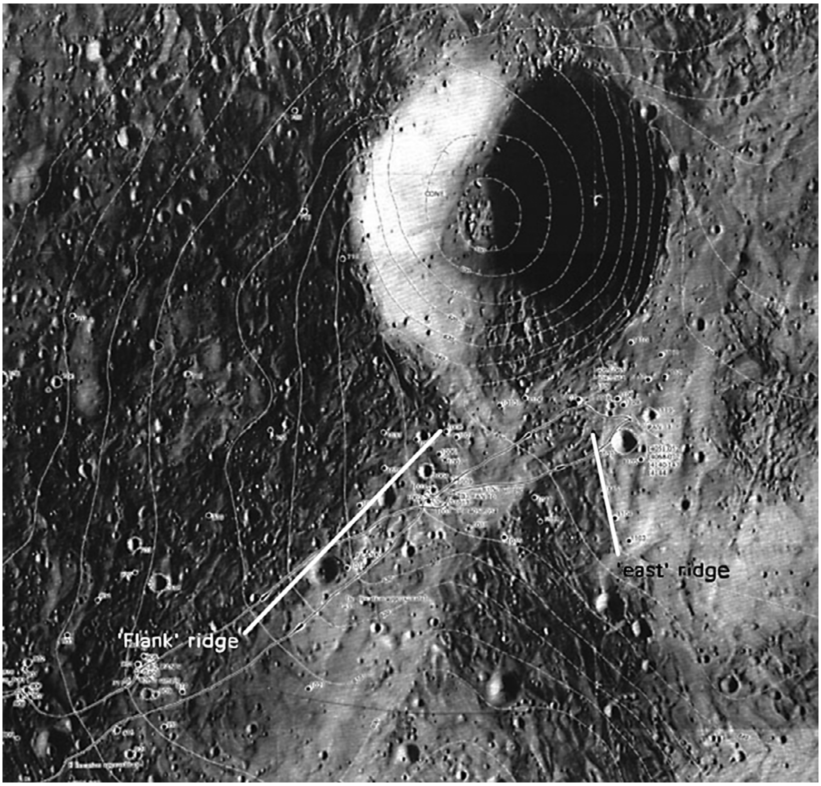

Figure 5.8. Cone Crater on the Moon (photo courtesy of NASA).

Crater, an artificial crater at the Nevada Test Site following the detonation of a nuclear device on December 8, 1968. The resulting crater measures about 985 feet across and 236 feet deep, a similar dimension to Cone Crater on the Moon (Moore 1977) (figure 5.8). Because Cone Crater was one of the objectives of Apollo 14, Schooner Crater made a logical training location. Apollo 14, 15, 16, and 17 mission personnel were trained there between 1970 and 1971 (figure 5.9).

The deserts of the western United States proved to exhibit many similarities with the expected geology of the Moon, and as such, they served as excellent training localities. Another site was near Taos at the Rio Grande Gorge in New Mexico, identified as similar to the Apollo 15 landing site. Near Taos, in north-central New Mexico, are areas that offer many striking similarities to the lunar landing site. At the Apollo

Figure 5.9. Apollo 16 astronauts: (*left to right*) lunar module pilot Charles M. Duke, commander John W. Young, and command module pilot Thomas K. Mattingly II during a training exercise at an undisclosed location in the western United States, in preparation for the lunar landing mission (photo 72-h-249, courtesy of NASA).

15 lunar site, the Hadley Rille is about 1 mile wide and about 1,000 feet deep. Near Taos, different segments of the Rio Grande have created a gorge varying from 1,000 feet to over 4,000 feet wide, with a depth of about 650 feet. Both the Rio Grande Gorge and the Hadley Rille are entrenched in basalt lava flows (NASA 2015i).

Spacesuit design testing was carried out in many unexpected locations, including central Oregon. Figure 5.10 shows NASA personnel testing spacesuits in the lava beds near McKenzie Pass, Oregon, in 1968.

Craters of the Moon, Idaho, provided views of a small crater that was the source of a large volume of extremely fluid lava, some of which formed a channel about 2 miles long, the end of which becomes a lava tube with much of the roof still intact. This was thought to be similar to lunar rilles (NASA 2015i).

Coconino Point, near Flagstaff, was the site for the final simulation for the Apollo 15, carried out in coordination with the science support teams at Mission Control in Houston. The exercise was to simulate Extra Vehicular Activities (EVAs) II and III in an area with similar morphology to the Apollo 15 landing site. Coconino Point on Gray Mountain simulated the Apennine Front, and the Little Colorado River Gorge simulated Hadley Rille. EVA II used a rover to traverse along the mountain front as scheduled for the actual mission. The mission encompassed three hours of descriptions, sampling with photo documentation, including taking panorama and 500mm photos, trenching, coring, and raking. EVA III used a rover to traverse along the gorge for about three hours and included the same tasks as EVA II plus penetrometer measurements designed to train astronauts on measuring consistency and hardness of geological samples (NASA 2015i). Another training session was at Lunar Crater near Tonopah, Nevada, a relatively young, little-eroded volcanic feature similar to some of the features expected at the Apollo 17 landing site (NASA 2015i).

Figure 5.10. NASA technicians and an astronaut testing a spacesuit design for mobility and durability near McKenzie Pass, Oregon, in 1968 (photo courtesy of University of Oregon Libraries).

Although almost all of the astronaut training occurred within the continental United States, occasional visits were made abroad to investigate geological formations not accessible elsewhere. Iceland was one such training location (figure 5.11).

However, of the many astronaut training locations, perhaps the ones that were believed to most closely resemble the surface of the Moon were places in Hawaii. Hawaii's appeal for geological, equipment, and mission objective training led to it being one of few locations that were visited by all the Apollo missions. Most of the training occurred on the Big Island of Hawaii, but anecdotal accounts provided by local residents indicate that more remote locations like Haleakala were used as well (Angus McKelvey, personal communication 2014). Interestingly, the authors could find no documentation to confirm Haleakala's role in astronaut training, suggesting that its role in the Apollo missions now remains exclusively in the memories of those who witnessed it. This underscores the importance of collecting oral histories from participants and witnesses as part of the historic preservation process.

Although not home to astronaut training facilities, Oklahoma is the only state in the United States that can boast an array of astronauts, scientists, and engineers who helped design, test, and send personnel to the Moon during every phase of the U.S. space program (Moore 2011). Eight Oklahomans served as astronauts: Leroy Gordon Cooper (Gemini 5); Thomas P. Stafford (Gemini 6 and 9, Apollo 10, Apollo-Soyuz Test Project); Fred Haise (Apollo 13); Stuart Roosa (Apollo 14); Owen Gariott (Apollo-Skylab, space shuttle); William Pogue (Apollo-Skylab); Shannon Lucid (space shuttle, Mir); and John Herrington (space shuttle, International Space Station) (Moore 2011). Nineteen flights between Mercury Faith 7 and STS-113/ISS had Oklahoman astronauts (Moore 2011). Countless more worked at Mission Control in Houston, Cape Canaveral, Huntsville's Marshall Space Flight Center, NASA's Ames Research Center, the Jet Propulsion Lab, and NASA headquarters in Washington, D.C. Forty-four engineers, scientists, and mathematicians from the U.S. space program have Oklahoma connections, and eighteen space probes and satellites ranging from Ranger 7–9 through Juno have ties to Oklahoma (Moore 2011). Although Oklahoma was

Figure 5.11. Astronauts Ken Mattingly (*left*) and Neil Armstrong (*right*) during a geology field training exercise in Iceland in 1967 (photo S67-33609, courtesy of NASA).

not a destination locality for astronaut training, Oklahoma's role in providing important personnel in the history of human spaceflight is impressive.

When Neil Armstrong took his famous first steps onto the lunar surface, he kicked around the soil and said, "Yes, the surface is fine and powdery." Gazing at the flat horizon, he took in the view. "Isn't that something! Magnificent sight out here." After collecting a contingency sample, Armstrong looked around and observed, "It has a stark beauty all its own. It's like much of the high desert of the United States. It's different, but it's very pretty out here" (NASA 2015g). The argument can be made that some of the most important factors in successful research and development in any industry include a foundation of strong academic science, ample funding and support, and the ability to replicate

real conditions during equipment testing and personnel training. What made these training facilities in the United States important historically was not just who was trained but also the qualities of the geographic locations. The challenges of legally protecting and preserving significant places such as these are described in the following chapter.

6

Legal Frameworks for Historic Preservation

Cultural resources preservation laws and policies have developed over time in response to the public's recognition of the economic and social importance of heritage and other cultural assets (Zorzin 2011). The American Antiquities Act of 1906 was the nation's first attempt to afford some level of protection and preservation to cultural resources. Since that time, nearly four dozen laws, regulations, executive orders, and guidelines specific to historic preservation have been passed by the federal government, largely in reaction to the public's demand to protect traditionally viewed cultural resources like archaeological sites and historic buildings on U.S. soil—those with terrestrial addresses, clearly defined ownership and legal jurisdiction, and coordinates tied to Earth (Westwood 2015). None specifically addresses space heritage.

Currently, and for the foreseeable future, the primary national regulatory context that factors into the preservation and management of space heritage sites is the National Historic Preservation Act (NHPA) of 1966, which was passed by Congress three years prior to the Apollo 11 landing. In doing so, Congress acknowledged that there are physical manifestations of our history—either under private or state ownership, or owned by the federal government—that are significant and worthy of proper management and preservation for future generations. Among the actions required by the NHPA was the establishment of the National Register of Historic Places (NRHP), which is a list of significant

sites that are afforded additional management and consideration at the time of their eligibility and in the future.

"Significance" from a historic preservation perspective is far from subjective; a property designated as legally significant meets at least one or more of four criteria for listing on the National Register and retains integrity. That does not imply that a site not meeting such criteria is not important to any given person or group, however. For example, Indian tribes, ethnic or religious groups, communities, professional and other organizations, or the public may ascribe a cultural, historical, or religious value to an archaeological site. The term *value* here refers to the site's worth and importance to them and their experience, regardless of whether the site can be deemed significant under the NRHP's definition of significance. For example, an archaeological site may be of historical or cultural value to the Church of Jesus Christ of Latter-day Saints or to an African American community or to the Order Sons of Italy in America, with or without it meeting the criteria for listing on the NRHP.

In the realm of space heritage, there is a growing number of professionals, present authors included, who value all space heritage sites as important and worthy of being evaluated for this significance, but not all sites will rise to the level that allows for listing on the NRHP. Only sites and historic properties that meet the eligibility criteria for inclusion on the NRHP and retain integrity are afforded additional consideration (and protection) during a project's undertaking or mission planning. The lead federal agency must take into account the effects that the project or mission will have on significant sites prior to authorizing or funding that undertaking, and the agency must consider ways to avoid, minimize, or mitigate any adverse effects. Through a well-defined evaluation and consultation process, the finite and nonrenewable nature of listed or eligible archaeological sites is considered, as well as the value these sites may have to different parties.

To be eligible for listing on the NRHP, sites or properties must meet at least one of the four criteria established by the National Park Service and possess integrity:

- Criterion A: is associated with events that have made a significant contribution to the broad patterns of our history;

- Criterion B: is associated with the lives of persons significant in our past;
- Criterion C: embodies the distinctive characteristics of a type, period, or method of construction, or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components may lack individual distinction; or
- Criterion D: has yielded, or may be likely to yield, information *important* in history or prehistory. (36 C.F.R. 60.4; emphasis added)

It is important to note that while historic properties are those that are typically more than fifty years of age (thereby meeting the threshold of "historic"), eligibility for inclusion on the NRHP does not factor in location or age. Also, there are numerous exceptions. According to 36 C.F.R. 60.4,

> Ordinarily cemeteries, birthplaces, or graves of historical figures, properties owned by religious institutions or used for religious purposes, structures that have been moved from their original locations, reconstructed historic buildings, properties primarily commemorative in nature, and properties that have achieved significance within the past fifty years shall not be considered eligible for the National Register. However, such properties will qualify if they are integral parts of districts that do meet the criteria or if they fall within the following categories:
>
> A. a religious property deriving primary significance from architectural or artistic distinction or historical importance; or
> B. a building or structure removed from its original location but which is significant primarily for architectural value, or which is the surviving structure most importantly associated with a historic person or event; or
> C. a birthplace or grave of a historical figure of outstanding importance if there is no appropriate site or building directly associated with his or her productive life; or

D. a cemetery which derives its primary significance from graves of persons of transcendent importance, from age, from distinctive design features, from association with historic events; or
E. a reconstructed building when accurately executed in a suitable environment and presented in a dignified manner as part of a restoration master plan, and when no other building or structure with the same association has survived; or
F. a property primarily commemorative in intent if design, age, tradition, or symbolic value has invested it with its own exceptional significance; or,
G. a property achieving significance within the past 50 years if it is of exceptional importance.

The last criterion, G, is the one that affords an exception for properties that have achieved significance recently (Westwood 2015): a property less than fifty years old can be nominated if it is of "exceptional importance." Moreover, some properties will satisfy only one criterion, while others may satisfy more than one. Tranquility Base on the Moon, representing the first human presence on another celestial body, is one that satisfies all four criteria, as well as exception criterion G.

Satisfying at least one of the eligibility criteria is not sufficient, alone, to ensure a determination of significance. The property must also retain integrity. Like *significance,* the term *integrity* has multiple meanings. To the public, integrity means that a property or site has physical substance—a rocket test stand that is still standing and functional would meet that definition, whereas a test stand in ruins may or may not.

Within the context of the NRHP, however, integrity is expressed through up to seven aspects: location, materials, workmanship, design, setting, feeling, and association. In this context, integrity is the ability of the property to convey its significance through physical features and context. An abandoned rocket test stand or launch site that lies in a state of disrepair may no longer exhibit integrity of materials, workmanship, and design, because the structure is no longer intact, but if its ties to an important event in history are still strong and if it is still

located where the event occurred, then it retains integrity of location, feeling, and association. At the present time, however, a site cannot be nominated to the NRHP based on retention of feeling and association alone: some aspect of physical integrity must remain that conveys the significance of the site.

For example, all that remains from the area where the fire occurred in the Apollo 1 command module in 1967 at Cape Canaveral that took the lives of astronauts Virgil "Gus" Grissom, Edward White II, and Roger Chaffee is a concrete superstructure (see figure 2.3). Although this test pad clearly lacks sufficient integrity of materials (physical integrity), the site is inextricably tied to a tragic, scientifically and historically important event in human space flight history—one that is also memorialized by the placement of a bench with the inscription of the names of the astronauts who perished there. What made that site significant in the first place was the association of important events and people at that place, and that association is not affected by the quality or quantity of original materials now located at the site. In a real sense, it has become a memorial.

Many of the space heritage sites profiled in this book meet at least one of the NRHP eligibility criteria and are therefore considered significant in an American legal context. Whether or not these sites have been formally listed on the NRHP is irrelevant; they need only be considered eligible for inclusion on the NRHP, under Executive Order 11593. Furthermore, the argument can be made that formally evaluating a property and making the statement that it is eligible for listing on the NRHP does not, in and of itself, render the property significant—it inherently either is or is not eligible for the NRHP, and those who recognize it formally through determining it eligible for or including it on the NRHP are only acknowledging the significance that was there all along.

A property that exhibits the highest levels of significance at a national level may be further designated a National Historic Landmark (NHL). These sites represent a select few, the upper echelon, of historic properties in the United States. Several space heritage sites on Earth have been designated as NHLs, including the Apollo Mission Control in Houston; the Saturn V Dynamic Test Stand in Huntsville, Alabama;

the Lunar Landing Research Facility in Hampton, Virginia; the Zero Gravity Research Facility in Cleveland; Launch Complex 33 at White Sands Missile Range, New Mexico; and nearly two dozen other facilities across the United States (see appendix B).

In 1984, the U.S. National Park Service commissioned a Man in Space Historic Landmark Theme Study, which inventoried sites in the United States that illustrated the space program in order to evaluate them for inclusion on the NRHP and/or as NHLs (Butowsky 1984, 1986, 1989). Supplementary to the Man in Space series, through the request of the National Park Advisory Board, the Astronomy and Astrophysics National Historic Landmark Theme Study was prepared in 1989. The subject of astronomy was first covered by the National Park Service as part of the National Survey of Historic Sites and Buildings report *The Arts and Sciences: Scientific Discoveries and Inventions, 1964.* Several NASA resources were also identified in the Astronomy and Astrophysics Study that were involved in the space program (Butowsky 1989).

The purpose of an NHL designation is to identify and recognize nationally significant sites. Landmarks are evaluated by the National Park System Advisory Board and designated by the secretary of the interior in accordance with the Historic Sites Act of 1935 and the NHPA of 1966. An NHL designation for the site extends special protections and consideration under federal law.

There were eight sites in the 1984 study associated with NASA's space program, including the Neutral Buoyancy Space Simulator, the Propulsion and Structural Test Facility, and the Saturn V Dynamic Test Stand at the George C. Marshall Space Flight Center in Huntsville, Alabama. In 1987 the Saturn V rocket on display at Marshall Space Flight Center was added. Huntsville, Alabama, became the home of Wernher von Braun and his research team after their work at White Sands Missile Range at the end of World War II. Between 1988 and 1991, there was a follow-up study from the National Park Service, the Man in Space Study of Alternatives, and the work of the Advisory Council on Historic Preservation (ACHP), the overarching advisory body for historic preservation in the United States, on these issues with NASA which led to the designation of twenty NHLs and the conclusion of

a programmatic agreement with NASA. However, these nominations also led to a pushback from the scientific and technological communities, who were concerned that listing properties on the NRHP could stop modifications to their facility, curtailing research capabilities, and could prevent ongoing scientific research at these facilities. This led to a joint request from the House Committee on Interior and Insular Affairs, the Subcommittee on National Parks and Public Lands, and the House Committee on Science, Space and Technology to the ACHP to undertake an analysis of preservation issues concerning federal support for highly scientific and technical facilities in 1991. In addition, private institutions receiving federal support through research grants pointed out that compliance with the NHPA would impose a burden on them. The report, *Balancing Historic Preservation Needs with the Operation of Highly Technical or Scientific Facilities*, produced five recommendations, one of them being that "the ACHP strongly recommends that Congress not enact legislation providing exemptions from or waivers of the administration of the NHPA for the benefits of specific Federal agencies or programs" (ACHP 1991: 62).

Once a site or property has been determined to be eligible for, or included on, the NRHP, the federal agency considering an undertaking or project must next consider whether the effects of their actions will adversely affect the property. According to the ACHP and regulations that implement the NHPA in 36 C.F.R. 800.5(a), an adverse effect occurs when "an undertaking may alter, directly or indirectly, any of the characteristics of a historic property that qualify the property for inclusion in the NRHP in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association."

Accordingly, any action that will cause an adverse effect or multiple effects is one that will diminish an eligible or listed site's integrity or negatively impact those characteristics that conveyed its significance in the first place and made it eligible for inclusion on the NRHP. Therefore, federal agencies, including NASA and the Federal Aviation Administration, must consider whether their missions or undertakings (such as hazardous materials abatement and facility abandonment) will have a negative effect on space heritage sites and properties either under their

ownership (Section 110 of the NHPA) or under private ownership but needing federal approval or funding (Section 106 of the NHPA).

The policy of the Department of Defense (DOD) is to manage and maintain all of its properties, not just historic buildings and structures, through a comprehensive program that considers the preservation of their historic, archaeological, architectural, and cultural values. However, the need to manage these resources (especially those regarding the space program) as mission-supporting assets and the need to ensure troop readiness place many of these potentially historic facilities at grave risk for disposal, removal, and demolition as surplus properties. The DOD has generally determined a building's useful life at fifty to seventy years and receives funding for new structures, not for rehabilitation (Donaldson 2006).

There are several ways in which a federal agency might resolve or reduce (mitigate) adverse effects on a significant property. Examples that may be appropriate for resources associated with space heritage include avoidance of the site in the undertaking, preserving sites and incorporating them into heritage tourism plans, extensive documentation, restoration, reconstruction, and adaptive reuse. Data recovery, a common method of mitigation, is the documentation and collection of important information that is represented only in physical form—such as detailed archival research, mapping, and photography through the Historic American Building Survey, Historic American Engineering Record, or Historic American Landscape Survey programs. As one criterion in considering appropriate mitigation, federal agencies can address how the community or the general public best benefits from the expenditure of public funds for preservation treatments. The public may derive greater benefit from a combination of more-limited data recovery that involves excavation at archaeological sites, brochures, exhibits, site tours, public lectures, websites, documentary videos, and history modules for use in schools. Using these means to achieve broader public involvement can lead to an increased appreciation of the past and a greater willingness to expend public funds in the pursuit of preservation goals (Donaldson 2012a).

However, the need for transparency in using public funding must be balanced with the need to protect sites from intentional or inadvertent

public damage. Underlying the various cultural resources laws, regulations, and executive orders is the need to maintain confidentiality of certain types of cultural resources. Under the premise that these resources are nonrenewable, fragile, and vulnerable to a black market economy, the exact locations of archaeological sites, in particular, are highly guarded by those agencies entrusted to protect them. In many cases, their locations cannot be protected, because the sites are well known or are publicly accessible in parks. Others, like Tranquility Base, are well known and mapped but are less threatened because of a lack of access attributable partly to the high cost of going to the Moon. Yet balancing the use of public dollars to maintain confidentiality with the public's right-to-know has not been easy.

In 1967, the passage of the Freedom of Information Act (FOIA) allowed the public the right to access and obtain the records from all federal agencies. The federal agencies must disclose any of the requested information from its citizens under FOIA unless disclosure would threaten interests such as personal privacy, national security, and law enforcement. The release of information about the locations of irreplaceable archaeological sites, however, can lead to increased visitation, looting, or damage to the sites, even by well-intentioned visitors. Mitigating this risk is an exemption from FOIA that prohibits federal agencies from disclosing confidential site locations to the public.

In all, there are nine exemptions that allow federal agencies to withhold information under FOIA; one deals with historic resources. This exception allows a federal agency to withhold information "specifically exempted from disclosure by statute" (5 U.S.C. 552(b)(3)). NHPA Section 304 (54 U.S.C. 300101 et seq.) is one of these statutes. Section 304 mandates that if grant assistance is being received by a federal agency under the NHPA, then the agency must "withhold from disclosure to the public, information about the location, character, or ownership of a historic resource" if the secretary of the interior and the federal agency agree that the release of the information may do harm. There are three conditions: "(1) cause a significant invasion of privacy, (2) impede the use of a traditional religious site by practitioners, and (3) risk harm to the historic resource." Other statutes and regulations under the NHPA whereby information is generated and the secretary of the interior must

consult with the Advisory Council on Historic Preservation (ACHP) are Section 106 and Section 110(f) whenever determinations are made to withhold such information. For similar reasons, the specific locations of resources that are not already designated in a public historical registry have been withheld from the following chapters. A general map of locations discussed in this book is provided in appendix A.

Evaluation of historic space exploration sites was initiated in the early 1980s through the 1990s; the focus of historic context development has been at the national level, primarily because of DOD and NASA guidance. While that approach has considerable logic, its results have met with mixed success; many reports have been rejected by reviewing agencies for their lack of consideration of local- or state-level contexts and associations (Donaldson 2012a). Consideration of state and local impacts appears to be primarily encouraged by agencies in states with few NASA resources, while state historic preservation officers reviewing numerous Apollo facilities appear to consider only national significance in the context of the history of the space race.

The rationale for the preparation of the historic context requires an understanding of the significance of both the broad and the specific historical events and persons associated with a property or installation, as well as how those events and persons are associated with the properties being evaluated. This understanding must be appreciated and understood by both the investigator and the reviewer. When the application of the space exploration historic context by federal agencies became prevalent, many broad, national-level historic contexts were prepared.

These include, among others, comprehensive general Cold War–era contexts prepared by NASA and the U.S. Army, Navy, and Air Force, as well as specific contexts relating to a variety of subjects, such as guided missile, communications, and radar systems and defense production during the period of space exploration. Both government and privately contracted historians have prepared these historic contexts.

As discussed earlier, the antiquated requirement to be at least fifty years old to be considered for inclusion on the NRHP without special considerations is problematic, particularly in a technological era during which so many important historical milestones occurred. Some of the

most important events in human history occurred less than fifty years ago, yet historic preservation of these sites must be vectored through an additional process. To meet the criteria of "exceptional importance" required for properties less than fifty years in age, a temporal association with the broad contexts is not enough. As a result, additional, more-focused historical research is always required for each property or installation being evaluated. The additional research ensures that properties be considered within the broadest possible range of contexts, an element of the process that is particularly important in cases where there are highly specialized missions, like space exploration, or where state or local associations are present and public sentiment and emotion may be involved. In the case of the latter, some military installations—in particular, remote facilities—are inextricably tied to a community and its economy. However, this is not necessarily a historically significant relationship.

As we move forward in preserving the tangible history of these rare and important sites, we continue to need improved or alternative mitigation and treatment options, the creation of a centralized repository and data clearinghouse, and updated historic building cost/benefit analyses. Additional priority needs include creating useable historic contexts, developing and expanding best management practices for Traditional Cultural Properties, and improving tools for identifying and evaluating cultural resources in inaccessible areas.

There is another class of cultural resource that transcends the modern political boundaries of nations to convey significance to the entire human species; space heritage sites that are associated with humankind's first movement into space fall into this category. Currently, the only "universal" or international historic preservation program on Earth is the World Heritage List, maintained by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) under the World Heritage Convention. Established out of international concern for the threats to archaeological sites in Egypt from the construction of the Aswan High Dam in the 1950s, the 1972 World Heritage Convention set forth mechanisms and funding to preserve cultural and natural sites of international significance to all of humanity. Sites eligible for preservation are those that exhibit outstanding universal value,

defined as "cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole" (UNESCO 2013a). Outstanding universal value is further qualified through the application of six selection criteria for cultural properties (UNESCO 2013a), whereby the site

i. represents a masterpiece of human creative genius;
ii. exhibits an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design;
iii. bears a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;
iv. is an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;
v. is an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change; or
vi. is directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance.

In July 2015, the World Heritage List included 1,031 properties composed of 802 cultural, 197 natural, and 32 mixed properties in 163 nations (UNESCO 2013b), with many more sites currently on the tentative lists for nations, which are awaiting eventual inscription. Of these, 23 are located in the United States and include well-known sites like Mesa Verde National Park, Independence Hall, the Statue of Liberty, and Taos Pueblo. In 2015, several sites were added, including the Birthplace of Jesus; Champagne Hillsides, Houses and Cellars in France; and the Spanish Colonial missions in San Antonio, Texas. Notable in 2015

was the inscription of numerous cultural landscapes, such as Papahanaumokuakea, Hawaii—likely reflecting the shift toward a recognition of the importance of context and relationship between features that are not easily defined by concrete foundations and park boundaries. The World Heritage List, however, has yet to reflect twentieth-century space heritage (Westwood 2015), and some of the most important sites to humanity—those associated with the human movement into outer space—are not represented. In fact, the notion of celestial space heritage sites and how it relates to historic preservation is quite new.

Although existing international historic preservation frameworks were not designed with space heritage sites in mind and, therefore, do not easily accommodate them, a new and forward-thinking paradigm can use precedent set here on Earth. This recent concept of "space law" needs to take into consideration the unique nature of space heritage sites—those objects, structures, features, and landscapes that may not be located on Earth or to which there is no clear title, or both.

Space is and perhaps always will be a place few humans will ever visit. In the scope of human evolution, it is the most recent frontier, only reached in the latter half of the twentieth and the beginning of the twenty-first century. As in any frontier, the rules and regulations of the mainland are tentative and stretched at best to fit these outlying areas. A frontier is, by definition, at the edge of a nation's territory and a difficult place to enforce its laws and regulations. In comparison to the rest of humanity's exploration and migration, first out of Africa and then from the Old to the New World, outer space can be seen as humanity's ultimate frontier.

Exploring frontiers also requires bravery, creativity, and advanced technology—the latter being "advanced" in comparison to technology of the day. Few disagree that Lewis and Clark's chronometer was critical to their exploration west; at $250, it was the most expensive single item in their possession (*National Geographic* 2015). Today, the chronometer is considered an ancient watch, but for the time, it was on the cutting edge, possessed only by the lucky few. Similarly, the tools and equipment left behind on the lunar surface by the Apollo 11 crew are archaic by today's standards, but for the time, they represented advanced technology that served as critical mission tools. Today, they no longer

measure up to the speed and efficiency of modern technology, but they dwarf it in their historical contexts.

Space and other celestial bodies have only been reached in extraordinary ways. Space and the Moon were first and are predominantly even now reached robotically. Only on a few occasions has there been an actual human presence—only twelve human beings have walked on the Moon. Space is a unique frontier in that a great commitment and level of technological sophistication are required to even get there. Because the assemblage of artifacts is so recent (post–AD 1950) and it is a place that continues to exponentially contain and accrue human artifacts, space is perceived of by the general public as not having much heritage value. Much of the material culture of space may not yet be thought of as significant. Therein lies a problem of what is perceived of as currently obsolete: an obsolete object is usually discarded or abandoned, but in a retrospect gained over decades or a half century, the object may be considered as valuable and worthy of preservation.

The past is also often perceived as being ancient. To the public, it should be at least hundreds, if not thousands, of years old. However, when key technological achievements in human history are considered, the first satellites in orbit and the first humans to leave the planet and create a site on the Moon should be ranked with the earliest stone tools made by our ancestors (approximately 2.5 million years ago), the harnessing of fire (as early as 1.6 million years ago), and the creation of complex art (circa 36,000 years ago). For close to 99 percent of human history (approximately 3 million years), material culture has been the only source of information that can be studied, usually by archaeologists. However, recent material culture—including that which is only a half century old—can still be studied in the same way. It is a common misconception that all that is important to know about modern culture comes in the form of documents, records, and visual and audio media. One fact noted by all space archaeologists is that in the past fifty years in a world of accelerating change, technologies are quickly superseded and, in some cases, discarded because their heritage value was not recognized at the time. Because of this, knowledge about the material record along with its documentation can be quickly lost by a flick of a wrist into a trash can.

The concept of culture, as discussed in the introduction to this volume, includes material culture that is the physical, tangible part of a culture ranging from stone arrowheads to the lunar excursion module. These can be used as sources of data, regardless of their age, to answer questions about human behavior and cultural change. Because space exploration is an ongoing living system, most space agencies and companies are rarely deeply invested in historic preservation; engineers tend to be more focused on future space engineering. Moreover, military secrecy can prevent the study of the documentary record. Much of the early exploration of space took place in the Cold War era, which was cloaked in secrecy by both the United States and the Soviet Union and their respective allies. Today, commercial confidentiality hinders the study of the documentary record. This means that the archaeological record of the Space Age is at risk from neglect, erosion, vandalism, and deliberate or inadvertent destruction (O'Leary 2009a).

There is also the sheer quantity of space heritage components. These include cultural landscapes, sites, features, structures, buildings, and objects. This book's main focus is on a small sample of the material culture related to American efforts in space, but the heritage of several other countries, especially Russia and the early Soviet sites, are equally significant and deserving of study and preservation. If we add to this archaeological assemblage space debris or parts and pieces of spacecraft floating in space, orbiting Earth in a graveyard orbit, or on other celestial bodies, the volume of the space heritage material culture is enormous (Gorman 2009)—arguably, almost unmeasurable. Even under the best environmental conditions and with comprehensive preservation laws and regulations, not all components of heritage are equally significant and cannot—and should not—be preserved.

Identifying appropriate candidates for preservation is difficult, however, and requires a special legal preservation framework. This is because space is a very different place. While much of the archaeological record on Earth can be assembled, described, and protected in a curation facility, buildings or sites can be preserved or reused, and terrestrial artifacts can be housed in museums or left in situ (in place) at an archaeological site, a critical and overwhelming portion of the record of space exploration cannot be accommodated in such a manner. It is

neither easily accessible nor neatly contained within the boundaries of a park or a nation. Instead, it is scattered over several continents or on other celestial bodies like the Moon or in orbit many miles above the Earth. The sites on the Moon have been indirectly protected by their remoteness and the cost to go there. The orbiting objects, especially those in low Earth orbit, will, for the most part, eventually deorbit and fall to Earth and be damaged, destroyed, or lost as they do so. Other orbiting objects, such as Vanguard, are actually being preserved in situ by their constant and predictable movement along a path in space. Therefore, an important question is raised: how do we provide for the protection and preservation of the significant archaeological record in such far-flung territories?

Managing the huge assemblage of space logically focuses on who owns and is responsible for decisions about space heritage; the question of who owns properties on Earth that evidence space history is much easier to answer. Most nations that recognize historical properties in their country have a set of laws and regulations governing how to evaluate the characteristics that make them important and which actions can be taken to preserve those qualities and characteristics that make them important. The United States has a series of historic preservation laws in place that date back to the turn of the twentieth century, as discussed earlier. However, existing national and international historic preservation laws do not specifically address off-Earth heritage. For example, the lunar sites created by astronauts in the Apollo program (1969–72) are not the kind of property envisioned as being covered by the NHPA in 1966 or eligible for inclusion on the NRHP, which was created three years before the first lunar landing (O'Leary 2009a). These laws and regulations provide the framework for properties significant to the nation's heritage, with only a few exceptions, within the boundaries of the United States. According to the law and its regulations, historic properties significant to the national heritage are considered "irreplaceable," and it is in the public interest that they be maintained for "future generations of Americans" (NHPA 1966).

Although the heritage of the United States is imperfectly addressed and maintained, the nation has created a legal framework for its pres-

ervation. There are national laws and regulations on shipwrecks and to ensure the protection of battlefields, Native American heritage, limited space-related sites in the United States, federal records, and other areas of historical and archaeological interest, but little or no congressional attention has been paid to the preservation of the sites and artifacts that evidence human activities in outer space (ACHP 1991).

The cultural resources in space and on other celestial bodies lie in a gray legal area governed, for the most part, only vaguely or nonspecifically, by international treaties and agreements. Although there are important cultural resources in space, there are few laws or agreements that specifically address protection for space heritage. As archaeologists and historic preservationists rather than legal experts, we are unable to present a comprehensive discussion of space law in this book, but we hope to provide a glimpse into the complexities of the legal situation of space heritage.

In 1957, in response to the International Geophysical Year and shortly after the launch of Sputnik, which exacerbated global tensions during the Cold War, the United Nations focused attention on the issues of outer space and urged its members that space be used exclusively for peaceful purposes (cited in Christol 1982). In 1967, the United Nations created the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, also known commonly as the Outer Space Treaty (OST), and the Ad Hoc Committee on the Peaceful Uses of Outer Space. Following an initial report by the committee, it became a permanent committee of the UN General Assembly (Doyle 2009: 743). From 1957 and into the early 1960s there were only two nations launching spacecraft and operating in space: the United States and the former Soviet Union (USSR). Stephen Doyle (2009: 743) comments that in order for any final agreements or treaties concerning space to be effective there have to be agreements on the formation of legal principles, rules, and policies between these two nations. Toward that end, the United Nations established two subcommittees: the Scientific and Technical Subcommittee and the Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space (COPUOS).

In 1963, COPUOS recommended a declaration of principles for activities in outer space. The UN General Assembly adopted the recommended principles in a unanimous approval resolution (UN Assembly Resolution 1962 [XVII]). Summarizing the work, Doyle (2009: 743) writes, "COPUOS address[ed] a wide range of issues, eventually producing five major treaties relating to the activities in outer space. In parallel with these treaties, which were proposed to and promulgated by the UN General Assembly, the COPUOS also recommended guiding principles relating generally to activities of states in space (1963), direct broadcasting by satellite (1983), remote sensing of earth from space (1986), the use of nuclear power in outer space (1992), and finally, a set of principles addressed international cooperation in the interest of developing countries (1996)."

There have been seventeen significant national laws motivated by the use of outer space that have been passed by the United States since the 1950s. At least thirty significant international treaties about the uses of space have been signed and ratified with many new international organizations (Doyle 2009). In the past fifty years, despite all of the above legalities promulgated because of the increase in spaceflight and space activity, there is not one among them that has specifically dealt with historic preservation.

That being said, the OST has some relevance to cultural properties. Three articles of the OST are relevant to the discussion: Articles I, II, and VIII. Article I of the treaty provides that "outer space, including the moon and other celestial bodies, shall be free for exploration and use by all states without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies" (Outer Space Treaty 1967).

Article II states that "outer space, including the moon and other celestial bodies, is not subject to appropriation by claim of sovereignty, by means of use or occupation, or by any other means" (Outer Space Treaty 1967). Essentially, the Moon cannot be claimed by any one nation. No one nation or individual can own the Moon; it is governed by treaty (O'Leary 2009b: 774). The last article addresses the responsibility and ownership of cultural property. Article VIII states that "a State

Party to the Treaty on whose registry an object launched into outer space is carried, shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to earth" (Outer Space Treaty 1967).

Article VIII signifies that those objects launched into outer space remain under the jurisdiction and are the responsibility of those nations that put them there. In the case of the United States, that ownership is under the auspices of NASA, as the lead federal agency. Beth Laura O'Leary (2009b: 775) notes that in 1985, this right of ownership was strengthened by the minutes of the NASA Artifacts Committee, which addressed the issue of transferring title of all the objects that remain at Tranquility Base on the Moon from the Apollo 11 mission. These artifacts would be transferred to the Smithsonian Institution's National Air and Space Museum (Jones 1985). Although no such formal transfer took place, the document states that NASA maintains title to the objects and does not consider the lunar artifacts to be abandoned property. Thus, the objects have informally some form of in situ preservation on the Moon.

NASA had entered into an agreement with the Smithsonian Institution, effective March 14, 1967, two years before the first lunar landing. The agreement concerned the custody and management of the agency's historical artifacts (Doyle 2009). Under the agreement, NASA artifacts no longer needed by NASA or other governmental agencies for technical purposes were to be transferred to the Smithsonian for curation. The terms of this agreement allow for custody, protection, preservation, and display, and the artifacts can be at the Smithsonian or on loan to other appropriate facilities.

There are also several museums in the District of Columbia, California, Florida, Texas, Alabama, Oklahoma, New York, and New Mexico and other places that display the various space artifacts. Currently, the command module from Apollo 11 is at the Smithsonian National Air and Space Museum in Washington, D.C. Among the other museums

that curate Apollo artifacts, the New Mexico Museum of Space History in Alamogordo exhibits an Apollo bio belt (cloth pouch) used by astronaut Ken Mattingly aboard Apollo 16 and a sample of moon rock collected by Apollo astronauts (New Mexico Museum of Space History 2015b).

While the OST does not mention heritage or cultural resources, one of the UN treaties does specifically mention heritage, but only in relationship to the natural environment (Walsh 2012). The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) is the international body that has drafted the space treaties. The 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, known as the "Moon Agreement," was entered into force on July 11, 1984, by the ratification of eleven signatories: Austria, Chile, France, Guatemala, India, Morocco, the Netherlands, Peru, the Philippines, Romania, and Uruguay (United Nations 2015). The United States, Russia, and China, which are the three prominent space-faring nations, are not parties to it, perhaps because of Article 11, which states that "the moon and its natural resources are the common heritage of mankind" (Bini 2010). These restrictions on future commercial exploitation of the Moon's natural resources may have played a factor in its failure to be ratified by the United States, Russia, and China.

One recent U.S. law in 2010 (Public Law No. 111-267, the National Aeronautics and Space Administration Authorization Act, Section 603), established that the space shuttle orbiters should be decommissioned "according to established safety and historic preservation procedures" (Walsh 2012: 236). As described in further detail in chapter 7, the space shuttle orbiters found homes at several American locations, with each paying NASA the costs of decommissioning and transporting the spacecraft.

A draft U.S. House of Representatives bill in 2010 (HR 5781) contained language, later removed, establishing a system of promoting historic preservation of lunar heritage (Walsh 2012). Another draft House of Representatives bill in 2010 designated Tranquility Base as a protected site under federal law; this bill (the Tranquility Base National Historic Landmark Act) was written but did not leave committee because its sponsor, Dan Lundgren of California (2005–13) failed

to win reelection. Given the limits of American law in space, neither of these proposed protections would have an effect on nations outside the United States and would be merely symbolic, but their passage as a national law would elevate the profile of the importance of preservation of these sites worldwide.

7

Preservation of Space Heritage Using Models from the Sea and Antarctica

Because of the limited attention given to date about the protection and preservation of the history of human exploration of space, there is no national or international comprehensive policy or body of regulations that specifically addresses the cultural resources of space and/or archaeological investigation. The legal situation of space heritage is in several ways similar to two other situations: the high seas and Antarctica. Outer space is analogous to the high seas and the continent of Antarctica because both are areas that lie beyond national territorial jurisdiction. Considered in contrast to some lands and oceans of the world, the archaeology of outer space has been substantially ignored by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), as well as by national legislatures (Doyle 2009).

An interesting fact to note is that one important tenet of archaeological method and theory, in situ preservation, comes directly from the earliest attempts at nonterrestrial archaeology, which began with underwater or marine archaeology in the 1930s with an investigation of a sunken sixteenth-century warship near Kalmar, Sweden. In 1963 the first American conference on underwater archaeology was held (O'Leary 2009c). Most marine archaeologists agree on a preference for preservation in situ of underwater cultural heritage (or the discovered location). Much of U.S. federal historic preservation law is dedicated to the mitigation of adverse impacts to those characteristics that make a property significant. One preferred method of lessening or obviating

damage is avoidance and in situ preservation, because the sites or artifacts maintain their locational integrity. This preference for in situ preservation or avoidance in the United Nations Convention on the Law of the Sea preserves the historic context of the site or object and also aids in determining its significance.

As discussed elsewhere in this book, the beginning of the Space Age can be investigated by archaeological studies: archaeology can be done anywhere humans have left material remains. In water, objects may be well preserved by a low deterioration rate because of the lack of oxygen and the absence of later intrusion by humans. The relatively benign environment of the world's oceans helps preserve artifacts. This is also true for outer space, where there is a lack of natural erosion and human activities that adversely affect cultural resources. In some ways the description of the early efforts by underwater archaeologists parallel efforts in the field of space archaeology and heritage.

When archaeological resources exist or are found at sea, there are several relevant international agreements. Unfortunately, the United States is not party to the two most important ones dealing with cultural resources in the world's oceans. The first United Nations Conference on the Law of the Sea (UNCLOS I) produced four separate international conventions in 1958, but important concerns such as the breadth of territorial water remained unaddressed. UNCLOS II in 1960 reached no new agreements. UNCLOS III in 1973 had some success by employing methods that had been used by the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS). Participating states avoided voting by agreeing on a consensus procedure, and no proposed text could be considered final unless there was a consensus among participants (or an absence of explicit objection) (Doyle 2009).

A new United Nations Convention on the Law of the Sea in 1982 had provisions on cultural resources and archaeological interest of the various states in materials found in and taken from the high seas. Article 1 of the 1982 convention defines the area of the high seas as "the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction" (quoted in Doyle 2009: 747). When the 1982 convention came to defining archaeological and historical objects in Article 149, it provides the following: "All objects of an archaeological and historical

nature found in the Area shall be preserved or disposed of for the benefit of mankind as a whole, particular regard being paid to the preferential rights of the State or country of origin, or the State of cultural origin, or the State of historical and archaeological origin." Some of these provisions are very vague and general: for example, how does one dispose of objects "for the benefit of mankind as a whole"?

A subsequent article in the UN Convention on the Law of the Sea contains more specific language about the duties of states (again limited to those that approved the Convention):

> Article 303—Archaeological and historical objects found at sea:
> 1. States have the duty to protect objects of an archaeological and historical nature found at sea and shall cooperate for this purpose.
> 2. In order to control traffic in such objects, the coastal State may, in applying article 33, presume that their removal from the seabed in the zone referred to in that article without its approval would result in an infringement within its territory or territorial sea of the laws and regulations referred to in that article.
> 3. Nothing in this article affects the rights of identifiable owners, the law of salvage or other rules of admiralty, or laws and practices with respect to cultural exchanges.
> 4. This article is without prejudice to other international agreements and rules of international law regarding the protection of objects of an archaeological and historical nature.

Stephen Doyle (2009: 747) comments that where the objects are discovered, they are covered by Article 33, which defines the "contiguous zone," nominally 24 miles outward from the nation's maritime baseline. Thus, Article 303 states that there is a duty to protect objects found in that zone and for nations to cooperate with each other for purposes of protection. Doyle (2009) finds this significant because in the 2001 adoption of the UNESCO Convention on the Protection of Underwater Cultural Heritage (referred to in the following discussion as the UNESCO Convention or the 2001 convention) was dedicated to protecting archaeological or historical resources.

The UNESCO Convention poses four main principles:

- Obligation to Preserve Underwater Cultural Heritage—States Parties should preserve underwater cultural heritage and take action accordingly. This does not mean that ratifying States would necessarily have to undertake archaeological excavations; they only have to take measures according to their capabilities. The Convention encourages scientific research and public access.
- In Situ Preservation as First Option—The in situ preservation of underwater cultural heritage (i.e. in its original location on the seafloor) should be considered as the first option before allowing or engaging in any further activities. The recovery of objects may, however, be authorized for the purpose of making a significant contribution to the protection or knowledge of underwater cultural heritage.
- No Commercial Exploitation—The 2001 Convention stipulates that underwater cultural heritage should not be commercially exploited for trade or speculation, and that it should not be irretrievably dispersed. This regulation is in conformity with the moral principles that already apply to cultural heritage on land. It is not to be understood as preventing archaeological research or tourist access.
- Training and Information Sharing—States Parties shall cooperate and exchange information, promote training in underwater archaeology and promote public awareness regarding the value and importance of Underwater Cultural Heritage (UNESCO 2001 Convention on the Protection of Underwater Cultural Heritage as quoted in Doyle 2009: 747)

The agreement was entered in force in 2009, when twenty nations had joined to accept it (Walsh 2012). The 2001 convention requires states to preserve underwater heritage for the benefit of humanity by taking appropriate action and places the responsibility on each state party to avoid commercial exploitation of heritage sites; even incidental damage to underwater sites is to be mitigated or prevented (Walsh 2012). The 2001 convention also notably defines underwater cultural heritage

as all traces of human existence having a cultural, historical, or archaeological character that have been partially or totally under water, periodically or continuously, for at least one hundred years (Doyle 2009). Yet one hundred years mimics a millennium when considering the more rapid pace of technological advancement in the space industry, as compared to maritime environments. It could be argued that a minimum age of fifty years is more appropriate for a similar convention for space heritage. That would also mirror the fifty-year threshold for historic properties on the National Register of Historic Places.

The primary principle of the 2001 convention mandates that underwater heritage be protected from commercial exploitation. Doyle (2009: 748) calls it a useful compromise because "any activity relating to underwater cultural heritage to which the convention applies is not subject to the laws of salvage or law of finds." An authorized activity is approved by a competent authority in conformity with the convention and thus serves to provide protection. The convention contains regulations concerning illicit trafficking in cultural resources, training in archaeology, and transfer of technology and information sharing so that public awareness is raised about the value and significance of underwater heritage (Article 2(10); Doyle 2009; Walsh 2012). That the rules were placed before the international committee and UNESCO by adopting the convention demonstrates that the international community can act for the preservation of archaeological and historical materials beyond national boundaries and in areas that are not within any nation's boundaries. As previously mentioned, however, to date, not all states have ratified the convention of 2001, and the list of non-participating nations includes the United States (Walsh 2012).

The U.S. Congress indicated a willingness to make laws applicable to its national interest in outer space by Public Law 101-580, which was adopted in 1990 (35 U.S.C. 10(105)). This law basically defines outer space to include the Moon and other celestial bodies beyond Earth's atmosphere and provides that the "inventions" made, used, or sold "under the control of the US" are, in effect, considered to be in the United States. Other space objects or components that are provided for by an international agreement fall under the conditions of that international

agreement (see Convention on Registration of Objects Launched into Outer Space).

Doyle (2009: 750) notes that at least there exist international precedents and precedent in U.S. national law and that "it is appropriate and useful to consider the extension of law regarding archaeology to outer space, even to the establishment of appropriate safeguards and guidelines to regulate archaeological interventions in outer space, on the Moon, or on other celestial bodies."

The Outer Space Treaty, which has as signatories most, if not all, of the world's states that are involved in space activities today, clearly provides for space activities being in compliance with international law. Importantly, Article 3 of the Outer Space Treaty (1967) states, "States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining peace and security and promoting international co-operation and understanding."

Those international conventions relating to archaeology beyond national boundaries should be considered, by extension, applicable to outer space. The benefits of formulating and ratifying agreements about cultural materials in analogous situations, such as underwater in extraterritorial waters outside of national boundaries, is that they can set precedents for justifying attention by the international community for consideration of a similar class of cultural resources—those in outer space and on other celestial bodies. The other remote and physically different environment besides the marine one is the continent of Antarctica. One of the last places on Earth to be explored, it is a hostile challenging environment hosting multiple nations, commercial enterprises, and individuals.

One of the last remote places on Earth to be reached, and only thinly settled, mostly by scientists, was Antarctica. The exploration and development of Antarctica left a sizable legacy of sites, objects, and intangible heritage, all of which lay beyond the borders of the nations that had created them. Several nations made claims on the territory of Antarctica (Walsh 2012). The management of the continent is done by

those states that have explored and done scientific research there according to the terms of a 1959 agreement. Justin St. P. Walsh (2012: 239) comments that territorial claims are "put on hold" by the agreement; the United Nations is not involved. Activities carried out in Antarctica are, by agreement, to be scientific in nature and are not to involve military endeavors. The nations that are party to the agreement may inspect the facilities of any other nation. A look at how the Antarctic Treaty System produced ways of evaluating and managing the historic sites and monuments there, including the successes and the faults alike, should provide guidance for managing the cultural resources of heritage off the Earth.

There are distinct parallels between the situation in Antarctica and that of outer space, both in their historic evolution and in the fact that both places are very remote. Prior to the Outer Space Treaty, President Eisenhower addressed the United Nations in 1960, stating that the Antarctic Treaty could help in developing international cooperation in space at the height of the Cold War (Lintott 2014). Space was not to be a zone of direct military confrontation, but it did become a place of competition during the Cold War (Gorman and O'Leary 2007).

Bryan Lintott (2014) discusses in detail the way in which Antarctic nations developed a workable system of cultural resource management for historic sites. All but one space-faring nation (the Islamic Republic of Iran) have endorsed the Antarctic Treaty System. The success of the Antarctic Treaty could lead to the adoption of a similar agreement for historic spacecraft, sites, and monuments in outer space and on other celestial bodies.

Although Antarctica was known about for centuries, not until just prior to World War II did several nations commit resources for major Antarctic expeditions. The major players included the United Kingdom, Argentina, and Chile. The first permanent base was established by the United Kingdom in 1944 for the purpose of consolidating its territorial claim; competing claims were made by both Chile and Argentina (Lintott 2014). It was during this period that the United States and the Soviet Union maintained a wary separation on this southernmost continent.

Shortly after the same International Geophysical Year (1957–58) that created a mandate to put the first satellite into Earth's orbit, where the greater interests of science would take precedence over territorial claims, the Antarctic Treaty was signed (in 1959); the treaty provided that its signees govern Antarctica by consensus, implementing their decisions through domestic laws and through Antarctic Treaty Consultative Meetings (ATCM). In 1961, the Antarctic Treaty Consultative Meetings approved a recommendation for protecting "tombs, buildings, and objects of historic interest" (Lintott 2014: unpaginated). Unfortunately, the recommendation did not provide a mechanism for review and agreement by the Antarctic Treaty System (Lintott 2014). Draft recommendations in 1968 tried to codify the criteria for significant sites, which focused on important events that happened in Antarctica. In 1972, forty-three historic monuments were recommended for formal approval (Lintott 2014). The push to protect the fragile Antarctic environment included a section on heritage that should not be damaged, removed, or destroyed. By 1995 at the Nineteenth Antarctic Treaty Consultative Meetings, New Zealand presented guidelines for the designation of historic sites, based on "international criteria" (Lintott 2014). Lintott (2014) acknowledges that these criteria have many similarities to the World Heritage Convention of 1972, which lists sites of universal importance. In 1940 the Chilean president Pedro Aguirre Cerda declared the establishment of the Chilean Antarctic Territory. With the attention of the British focused elsewhere during World War II, Argentina occupied British bases in the Antarctic Peninsula region. Argentina joined the United Kingdom, New Zealand, Australia, France, Norway, and Chile, becoming the seventh country to lay formal claims on this remote region (Mulvaney 2001). To complicate matters, Nazi Germany's U-boats had destroyed a fleet of Norwegian whalers off Norway's Antarctic claim in the east called Queen Maud Land. The actions of these countries made the area ripe for conflict (Mulvaney 2001). The criteria for Antarctica reflect its contested exploration and its being set aside as an area of peace and cooperation in the name of science. The limitation of the heritage system is that there is only one level of classification for redundant structures (such

as explorers' huts). A nation must choose whether a structure reaches historic site and monument status; if not, and if the structure can be safely environmentally removed, then it can be taken away.

The most significant addition to the Antarctic Treaty regarding cultural resource management is the 1991 Environmental Protection Protocol (EPP) and its annexes. This document outlines the ways in which those involved parties are responsible for protecting the environment. It specifically includes areas of historical significance in its definition of the environment (Walsh 2012: 239). Article 3(2) of the EPP states that "activities in the Antarctic Treaty areas shall be planned and conducted so as to avoid . . . degradation of, or substantial risk to, areas of biological, scientific, historic, aesthetic, or wilderness significance."

In addition, the EPP requires historic management and maintenance plans for sites applying for protected status and also requires that the plans must be updated (Walsh 2012). The management plans must regulate access to the area and permission for any collections. Despite being such a remote place on Earth, Antarctica recently had an annual high of over 46,000 tourists when people were drawn to the centennial in 2011 of Norwegian explorer Roald Amundsen's arrival to the South Pole in 1911, with promotional efforts for tourists to ski and visit sites along his route (Walsh 2012). The body of Antarctic treaties and protocols provides a way to control and limit the impacts of future tourism.

It would improve the situation if the International Council on Monuments and Sites (ICOMOS), especially the International Polar Heritage Committee, an advisory body to UNESCO, could undertake an independent review of proposals for designation. While Robert Falcon Scott's and Ernest Shackleton's sites of exploration from the early twentieth century underwent conservation work in the 1950s, New Zealand is preserving a place of research in Antarctica from the 1950s under its charter (ICOMOS New Zealand 2010). The New Zealand site is significantly less than one hundred years old, a standard for most nations defining antiquities in their historic preservation laws. Lintott (2014) also reports that in 2007 the topic of the use of Antarctica as an analogue in cultural resource management for Apollo sites on the Moon was

presented at the Mutual Concerns of Air and Space Museums Seminar at the Smithsonian Institution in Washington, D.C.

There is value here in noting that there has been a steadily increasing interest by archaeologists and historic preservationists in exploring and advocating for consideration of what has come to be called space archaeology and heritage. Mostly as symbolic actions, several states have been involved in attempting to recognize and legally preserve the Apollo 11 Tranquility Base site on the Moon. In 2006, New Mexico included Tranquility Base in the state's Archaeological Research Management System's database. Known as Laboratory of Anthropology (LA) 2,000,000, the Tranquility Base site is part of the state's more than 156,000 archaeological and historical sites found in New Mexico. Although LA 2,000,000 is on the lunar surface, its coordinates are tied to its host, the New Mexico Museum of Space History, in Alamogordo.

Initially, California in January 2010 and then New Mexico in April 2010 designated the objects and structures at Tranquility Base to their respective state registers of cultural properties. Because no form of state government has jurisdiction over celestial bodies like the Moon, the state agencies consider only the objects or artifacts, not the actual site, to be protected by state laws. Each designation happened because the proponents of the nominations described the historic relationship of their state to the events that led to the first lunar landing. Each state justified its decision on the basis of where within its borders NASA, scientists, military bases, and multiple contractors and scientists designed and tested the equipment that led to the Apollo 11 landing. Each designation describes the Tranquility Base assemblage in its historic context as an archaeological site. The California and New Mexico state nominations were followed by a resolution in 2014 by the Hawaiʻi State Legislature, which recognized the significance of this most iconic lunar site (Hawaiʻi 2014).

Dirk Spennemann (2004) has recognized the complexities of nominating a site's objects and not the actual physical location of the site on the Moon. If the moon's surface cannot be included, what is the status of the astronauts' footprints and trails made by Apollo 11's Neil Armstrong and Buzz Aldrin? They exist as features, not objects, on the

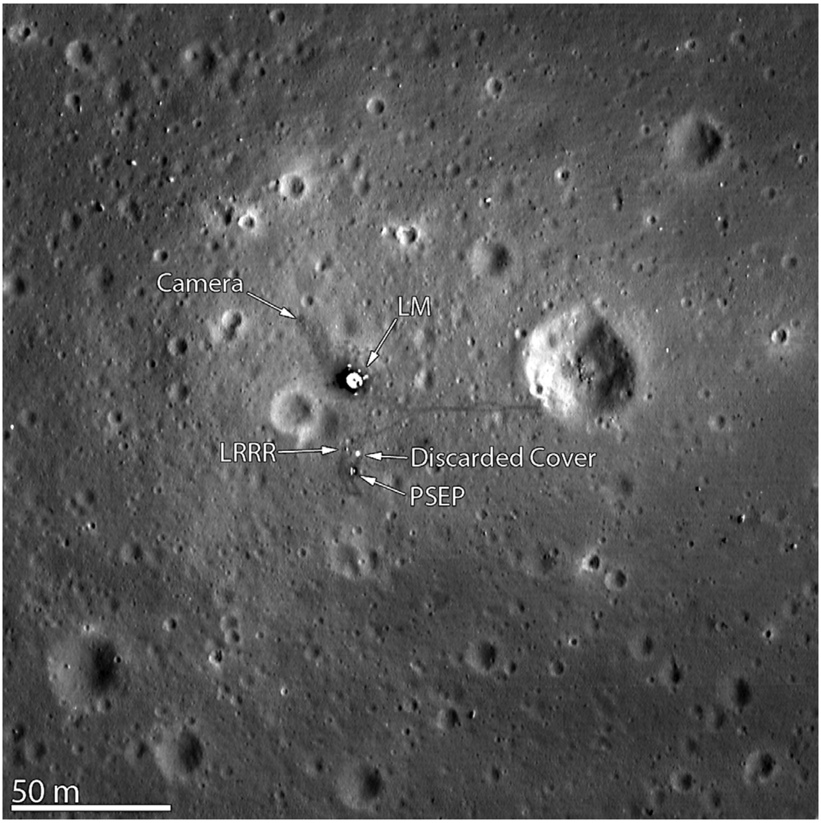

Figure 7.1. Apollo 11 lunar landing site taken by Lunar Reconnaissance Orbiter, 2009 (photo courtesy of NASA).

lunar landscape. Because of the relatively benign nature of the Moon's environment, the footprints are well preserved. This idea is corroborated by the digital images taken by the Lunar Reconnaissance Orbiter in 2009, which created digital images of the lunar surface and clearly show the foot trails at Tranquility Base (see figure 7.1).

These recent images of the features offer clear evidence of human presence on another celestial body, but according to the Outer Space Treaty, they cannot be governed by a nation's laws. Walsh (2012: 237) eloquently writes, "It is clear that an international solution is needed for this international problem."

All of the sites in Butowsky's 1984 Man in Space study were within the United States. This makes sense in terms of where the U.S. federal

preservation law applies, but the study fails to go far enough. All the sites in the United States are linked historically to others around the world that contributed their scientists, physicists, and engineers in developing an understanding of the parameters of outer space. Although they worked within the time frame of the Cold War (1946–89), scientists in the Soviet Union, Germany, and the United States alike relied on previous discoveries made by their predecessors from around the world. Also, Butowsky's 1984 study leaves out the most important and critical component: the sites in space and on another celestial body, the Moon. Alice Gorman (2005) is one of the first archaeologists to look at the history and material culture of space as part of a much larger cultural landscape. This landscape is at a much larger scale than any kind of cultural landscape on Earth and falls in a legal gray area of preservation.

The concept of a cultural landscape is what the 1972 World Heritage Convention defines as "the combined works of nature and man" (UNESCO 2013a). Space can be seen as a landscape that includes the ultimate wilderness—off the Earth. The concept of landscape is useful because it is so inclusive of material culture as well as nonmaterial components (O'Leary 2009c). It can include the landscape of those places and people who were outside of the science and engineering field who participated, many unwillingly, during the beginning of the space exploration. Inclusion in the landscape of space would embrace the slave labor at Nazi factories at Peenemünde, Germany, where Wernher von Braun directed work on the V-2 rocket during World War II. It would include those whose lands were co-opted by the government, such as the indigenous people at the Woomera rocket range in southern Australia or the ranching families in the Tularosa Basin whose lands were made part of White Sands Missile Range. When the elements of space heritage are viewed in their entirety, the numbers of technology, buildings, structures, objects, and places of all kinds are in the millions. A way to assess significance and prioritize preservation is critical, especially when faced with decisions of preservation and protection (O'Leary 2009b).

The earlier (2000–2003) Lunar Legacy Project at New Mexico State University, which was funded through the New Mexico Space Grant

Consortium by NASA, along with the later efforts to nominate the Tranquility Base site to the California and New Mexico state registers of cultural properties, are actions believed to have contributed to NASA's reconsideration of their policies on lunar preservation. In 2001, the Lunar Legacy Project proposed to both NASA and the National Park Service's Keeper of the National Register of Historic Places that Tranquility Base should be considered for designation as a National Historic Landmark (NHL). The responses by NASA's deputy general counsel, Robert Stephens, and the Keeper of the National Register of Historic Places, Carol Shull, at the time were clearly a coordinated rejection. NASA found that listing the lunar site as an NHL was contrary to the Outer Space Treaty and would be perceived by the international community as a claim of sovereignty by the United States. The Keeper's response centered on the recent policy determination that the Moon could not contain an NHL because the National Park Service did not have sufficient jurisdiction and such a designation was not appropriate. Shull wrote that the National Park Service could not "exercise our nominating authority over resources on the Moon" (O'Leary 2009b: 775). However, both domestic and international media picked up the story of these efforts, and this sparked many popular articles and radio and television interviews with the Lunar Legacy Project team. Clearly, it got people's attention.

Three ideas fascinated the public at the time: first, that archaeology could be applicable to outer space; second, that a recent site (less than fifty years old) could be considered of archaeological significance; and third, that the lunar landing site is important and should be protected. This last idea has met with almost unanimous agreement among the public, both nationally and internationally. The first lunar landing was experienced by millions of people worldwide, if only vicariously. What also intrigued and awakened the consciousness of the public was that the unique material evidence of the first humans on another celestial body lay in a gray legal area of protective laws that made it vulnerable to future damage or destruction (O'Leary 2009c). One of the best outcomes of the Lunar Legacy Project was bringing the issue of lunar preservation directly to the preservation authorities in the United States (O'Leary 2009b). Subsequently, the emerging field of space archaeology

and heritage grew as an academic subdiscipline after 2001, with multiple national and international conferences where papers were given, including meetings of the Society for American Archaeology, the International Council on Monuments and Sites (ICOMOS), and the World Archaeological Congress.

While public and archaeological interest in preserving the Apollo 11 lunar landing site increased, there was also discussion among heritage practitioners and museum curators (Lintott 2014). On September 13, 2007, an American company, Google, announced a Lunar XPrize. This is a competition by Google for the first private robotic expeditions to the Moon. Although the original dates for completing the competition have shifted to the future beyond 2015, the competition offers $20 million to the first private team to land a rover on the Moon, travel 500 meters, and send a high-definition video back to Earth. A "Heritage Bonus" of $1 million is offered for imaging a lunar archaeological site, like Tranquility Base. This second feat became controversial for the Lunar XPrize Foundation, even though the rules state that the foundation must approve landing plans in advance "to eliminate unnecessary risks to the historically significant sites of interest" (Lintott 2014). There was no discussion of how to judge "unnecessary risks" or what steps, if any, are recommended to help competitors avoid damaging the sites. Tranquility Base was a tempting, desired target for two of the teams (Walsh 2012: 235). Several space heritage archaeologists argued that the Heritage Bonus was a dangerous goal for untried private spacecraft (O'Leary 2009a; Thomas and Walsh 2009). In 2013 there were accidents of the unmanned Falcon 9 rocket, launched by SpaceX, which may be a premonition of things to come if the private space industry attempts to "safely" visit Tranquility Base using robotics remotely controlled from Earth. However, in December 2015 and in April 2016, SpaceX accomplished a nearly unimaginable feat by launching the Falcon 9 rocket and then executing controlled vertical landings, the 2016 landing on a drone ship at sea, demonstrating the concept of reusable rockets and underscoring the rapid technological advancements that may soon take the private sector to the Moon and beyond.

In 2010, NASA was contacted by several representatives of commercial entities "seeking guidance for approaching U.S. Government space

assets on the lunar surface—out of respect for hardware ownership, and a sincere desire to protect general scientific and historic aspects of these sites" (NASA 2011: 5). A panel of lunar experts across NASA and selected "external" experts from the scientific, legal, and historic preservation communities (including one of this book's authors, Beth Laura O'Leary, and Roger Launius of the Smithsonian National Air and Space Museum) were asked to provide some initial guidance for the writing of recommendations. NASA stated that there was no precedent for the situation and no "U.S. Government guidelines for spacecraft visiting the areas of existing U.S. Government (USG) owned lunar hardware" (NASA 2011: 5). It was a significant step for NASA—in fact, for any government or agency—to advance protection for space heritage. On July 20, 2011, NASA produced a white paper titled *NASA's Recommendations to Space-Faring Entities: How to Protect and Preserve the Historic and Scientific Value of U.S. Government Lunar Artifacts.*

The recommendations, while speaking volumes, do not carry the force of law. In 2012, Google agreed to the guidelines, although they carry no legal repercussions if violated (NASA 2012). Some Lunar XPrize competitors responded to the white paper by avowing to cancel their controversial plans to visit Tranquility Base, although the other sites still are within the parameters of the Heritage Bonus. The recommendations do not entirely address the issue of activities on the actual lunar surface or regolith. NASA (2011: 5) states,

> These recommendations are intended to apply to United States Government artifacts on the lunar surface—these artifacts include:
>
> A. Apollo lunar surface landing and roving hardware;
> B. Unmanned lunar surface landing sites (e.g. Surveyor sites);
> C. Impact sites (e.g. Ranger, S-IVB, LCROSS, lunar module [LM] ascent stage);
> D. USG experiments left on the lunar surface, tools, equipment, miscellaneous EVA hardware; and
> E. Specific indicators of U.S. human, human-robotic lunar presence, including footprints, rover tracks etc., although

> not all anthropogenic indicators are protected as identified in the recommendations. (NASA 2011: 5)

Although there was no following documentation or amendment to date, NASA states in the 2011 document that the agency has "begun engaging in dialogue with foreign space agencies, as appropriate" (NASA 2011: 5). In effect, NASA is aware of the necessity of interactions with other nations. No U.S. federal preservation laws are cited in the document; NASA's recommendations cite the NASA Act and U.S. federal property laws. The document states that the "recommendations are not legal requirements; rather they are technical recommendations for consideration by interested entities" (NASA 2011: 6). NASA cites its commitment to meeting its responsibilities under international law, specifically the 1967 UN Outer Space Treaty. The agency recognizes that the recommendations may evolve and promotes the development of "appropriate recommendations," such as in the document, with both private entities and foreign governments.

NASA's 2011 recommendations are intended to apply to U.S. government artifacts on the lunar surface sites and mitigate adverse impacts including the avoidance of biological, chemical, and other kinds of contamination. The recommendations provide limits on the descent and landing profiles to minimize damage to the artifacts and sites by rocket landings or flights over the areas; establish artifact boundaries that encompass artifacts at sites to prohibit interactions or visitations to those areas to protect the artifacts; apply protective measures for operational scientific equipment such as the lunar laser retroreflectors; and emphasize NASA's authority to approve scientific investigations for future visits (NASA 2011).

The Apollo 11 and 17 sites are set aside for special consideration. The first site, of course, is the iconic first lunar landing site, and Apollo 17 is the last site visited by U.S. astronauts in 1972. The Apollo 11 and 17 sites are treated as unique by prohibiting visits to any part of the site and defining the artifact boundary (AB) as a hard boundary with a radius of 75 meters for Apollo 11 and a radius of 225 meters from the lunar module descent stage at the Apollo 17 site. Based on scientific analyses

of previous historic data on the descent and landing of historic spacecraft, there is a "keep out zone" measuring 2 kilometers in radius for the descent and approach of spacecraft near the historic lander sites (such as Apollo and Surveyor) and a "keep out zone" of 0.5 kilometer for the heritage impact sites (such as Ranger S-IVB) (NASA 2011: 7).

One major problem that may develop is the concept of the artifact boundary, which is defined as "established to specifically encompass all artifacts at a particular site to prohibit interactions/visitation within that area in order to protect the artifacts of interest: descent state, lunar rover, flag, Apollo Lunar Surface Experiments Package (ALSEP) experiments, etc." (NASA 2011: 8). This artifact boundary assumes that the relatively inexperienced crew of a privately funded spacecraft could know the precise lunar location of all artifacts and features and actually control a landing far enough away from a historic landing site to ensure that the artifacts would not be adversely impacted. It assumes that they would be capable of respecting NASA's guidelines. These recommendations assume that future spacecraft will have the technical capacity (and its operator, whether on-site or remote, the technical skill set) to maneuver at such a fine scale on the lunar surface. The history of lunar exploration illustrates that the Apollo program's landings did not always go as planned, either. For example, the Apollo 11 actual planned landing site was changed, and Armstrong guided the lunar module to a markedly distant location from that originally proposed.

NASA's 2011 recommendations provide a fairly comprehensive catalogue of artifacts and sites created by the agency's flights to the Moon, although no subsequent archaeological survey, even by remote sensing, has ever been done. NASA's recommendations include all American impacts and landings on the Moon, which in itself is a large accomplishment, as well as providing scientific data on the physical risks to Apollo landing sites. It must be remembered also that some of these sites are still actively gathering data; several Apollo sites contain laser ranging retroreflectors that continue to provide data about the solar system and the effects of the long-term exposure on human material culture in a lunar environment. As such, NASA's recommendations provide interim advice on future lunar vehicle design and mission

planning for future space-faring private or national and international governmental agencies but have no teeth.

While there are technical flaws and details still to be addressed, the recommendations are more than a step in the right direction. From the perspective of the initial responses from NASA in 2001, the 2011 document can be viewed as "a giant leap" for historic preservation (O'Leary 2015: 9). The guidelines, as well as the actions by U.S. states that put the lunar artifacts on their state registers and acknowledge space heritage, testify to the view of the public that the components of sites like Tranquility Base are a significant part of humanity's scientific heritage and worthy of preservation (Donaldson 2010).

In conclusion, today's collection of historic preservation laws, regulations, and policies constitutes a largely reactive and Earth-bound regulatory framework that has been patched together over a century in an effort to quell the loss of human history. Those laws that have the potential to protect space heritage sites, such as the American Antiquities Act and the National Historic Preservation Act, were passed long before human space travel was even remotely feasible, and little has been done to amend laws to accommodate the paradigm shifts in cultural resource management that led to the recognition of cultural landscapes, discontiguous archaeological districts, and moveable objects or structures. While the World Heritage Convention affords an opportunity for multiple properties to be linked through transboundary or transnational nominations, even those must be tied to real property governed by nations. International treaties that guide human activities in international waters, Antarctica, and airspace on the Earth and the Moon provide models for historic preservation, but none directly addresses the preservation of humankind's collective space heritage sites. It is time for a change.

8

Threats to Space Heritage Sites

All heritage is threatened. Threats to material culture can be caused by natural forces in the environment or by human presence. The cultural effects include human reuse of the site through time such that a site may demonstrate multiple periods of occupation over time. In effect, the site reveals evidence of an assemblage of artifacts and features from different time periods. A Native American site in the American Southwest may have prehistoric indigenous ceramics and remains of semisubterranean houses, but it may also contain later features like seventeenth-century Spanish-designed irrigation canals and colonial commercial pottery, such as majolica from Puebla, Mexico. Cultural impacts to a site can adversely affect the integrity of the location and material remains when portions of the site are altered, whether directly or indirectly, by activities in the present. Loss of a site and its context can be inadvertent, as a result of neglect, or it can involve deliberate destruction from actual looting and vandalism.

The threats to our space heritage are equally diverse. One of the most basic of them is the lack of present understanding of space heritage importance in contemporary times. Much of the cultural material of space history is so recent that it may not be considered important enough to preserve. As discussed in the previous chapters, what is perceived of as obsolete is frequently discarded or abandoned, although it may, in the future, be considered valuable and significant.

However, perhaps the greatest threat to the facilities and sites related to space heritage on Earth is the lack of proper identification and management in favor of current operations. The rapidly changing

technology of space exploration is rendering many facilities obsolete, often long before they meet the fifty-year threshold for significance under the National Register of Historic Places (ACHP 1991: 19–20) (see chapters 6 and 7). National Register Bulletin 15 (Sherfly and Luce 1990) states, "Fifty years is a general estimate of the time needed to develop historical perspective and to evaluate significance. This consideration guards against the listing of properties of passing contemporary interest and ensures that the National Register is a list of truly historic places." It further exemplifies the achievement of significance within the past fifty years by citing space heritage sites: "The phrase 'exceptional importance' may be applied to the extraordinary importance of an event or to an entire category of resources so fragile that survivors of any age are unusual. Properties listed that had attained significance in less than 50 years include the launch pad at Cape Canaveral from which men first traveled to the moon, the home of nationally prominent playwright Eugene O'Neill, and the Chrysler Building (New York), which is significant as the epitome of the 'Style Moderne' architecture" (Sherfly and Luce 1990: 30).

In addition, with few exceptions, nearly all of the places, objects, and structures directly associated with the Apollo missions are currently less than fifty years in age. It is critical that federal agencies, including NASA, have the foresight to recognize the potential significance of facilities and manage them appropriately until they are understood and described in their historical perspective and context, and evaluated accordingly, and until the antiquated fifty-year standard is replaced with criteria that do not specify age. Cape Canaveral and Kennedy Space Center are good examples of the need for this heightened awareness.

Other threats include environmental impacts. These occur because of the natural processes of erosion, wind, water, and temperature changes. All environmental forces have the ability to continuously affect archaeological sites on Earth. The forces in space are different. In some cases, the effects on cultural material are relatively benign. For example, the lack of wind or water on the lunar surface has helped protect features like the footprints of the first humans at Tranquility Base, but the drastic temperature swings of 260 degrees Fahrenheit to -280 degrees Fahrenheit between lunar day and night have physical

effects on the many kinds of metals and materials flown there. Radiation, micrometeorites, cosmic rays, and solar winds also impact cultural resources.

Edward Staski and Roger Gerke (2009) argue that it is a common assumption that there are many adverse impacts on cultural resources in space, which is perceived of as a hostile place. Space is a place where humans have spent very little time and special precautions must be taken to even be there; however, space is relatively benign because of the few effects of natural processes. For example, on the Moon, a significant number of resources can be found in what archaeologists refer to as "time capsule sites" (Staski and Gerke 2009: 513). Time capsules are sites that result from single episodes of human behavior or a very short period of deposition.

The Apollo 11 astronauts Neil Armstrong and Buzz Aldrin spent a total of twenty-one hours on the lunar surface and created a historical site on the Moon on July 20, 1969. There can be a great range and amount of information recovered from that episode. Yet the argument has been made that because these time capsules are not ceremonial, their creation was unintentional and their contents are more generally representative of life at the time they were created (Jarvis 2002).

There are some data about the effects of the lunar environment on the assemblage of artifacts from the Surveyor 3 robotic probe that was investigated by the Apollo 12 astronauts on the lunar surface in 1969. Surveyor 3 was launched on April 17, 1967, and landed two days later on the Ocean of Storms on the Moon (McNamara 2001). Thirty-one months later, the Apollo 12 lunar module landed around 600 feet from this first soft-landed probe, and astronauts Pete Conrad and Alan Bean began an evaluation and collection of parts from the Surveyor 3 site (figure 8.1) (Staski and Gerke 2009).

In an archaeological fashion, the astronauts examined and photographed the site and "removed selected parts and enclosed soil for return to Earth" (Carroll et al. 1972). NASA's purpose was to look at the effects of the space environment on the hardware and materials after being on the Moon, but Bean and Conrad's activities can be considered archaeological data recovery (Staski and Gerke 2009: 514). P. J. Capelotti (2004: 50) calls it the first archaeological fieldwork conducted

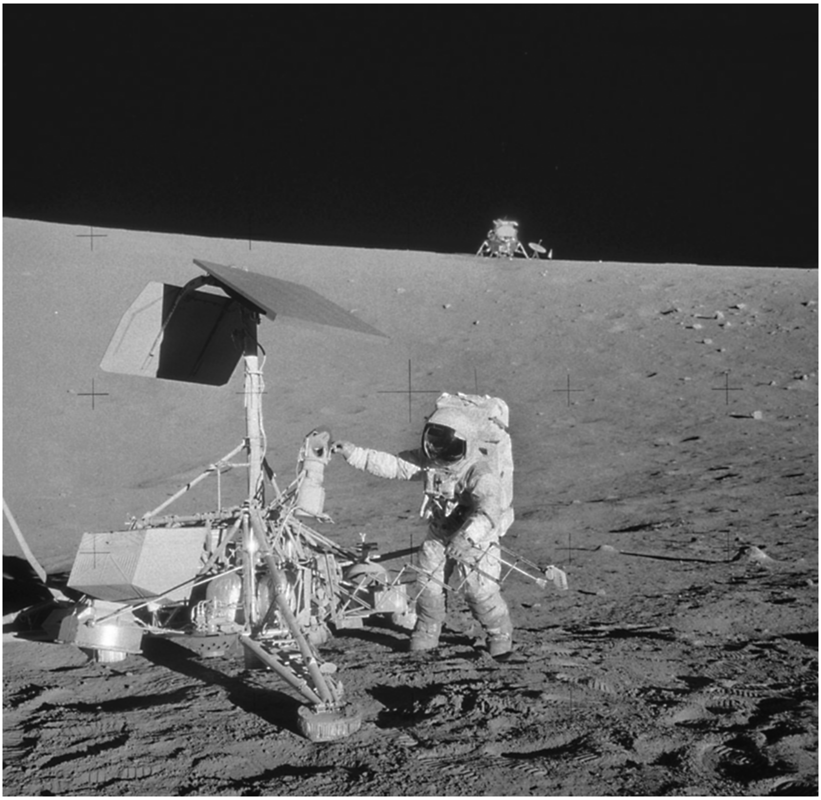

Figure 8.1. Surveyor 3 with Apollo 12 astronaut on the lunar surface (photo courtesy of NASA).

at an exoatmospheric location and writes, "The mission of Apollo 12 provided the first example of aerospace archaeology, extraterrestrial archaeology and—perhaps more significant for the history of the discipline—formational archaeology, the study of environmental and cultural forces upon the life history of human artifacts in space."

What the Apollo 12 report on Surveyor 3 offers is unique regarding natural formation processes, even if the purpose was not archaeological but was to be used to improve and create more-robust and longer-lasting space equipment. Moreover, what Conrad and Bean did was to affect the cultural resources at the Surveyor 3 site for scientific purposes and document their activities and collection policies. Their activities, unbeknownst to them, impacted the site and would be considered by

archaeologists as cultural formation processes, those processes that affect the archaeological and historical record resulting from human behavior (Schiffer 1987; Staski 2000). Our nation must take action to prevent future impacts to important space heritage sites by those who are not aware of the effect of their actions.

Conrad and Bean were the first to revisit a lunar site in situ, but they will not be the last. Visits to the early space sites will likely happen in the future with the advent of commercial space travel to the Moon. In fact, NASA is aware of the future of "space tourism" and other nations landing on the lunar surface primarily to visit the important historic sites there, as evident from the publication of *NASA's Recommendations to Space-Faring Entities: How to Protect and Preserve the Historic and Scientific Value of U.S. Government Lunar Artifacts* in 2011.

As discussed previously, NASA describes the document as a series of recommendations and "associated rationale for spacecraft planning to visit U.S. heritage lunar sites." It was meant to be an interim document "until more formal U.S. government guidance is developed and perhaps a multilateral approach is developed to reflect various nations' views on lunar hardware of scientific and historic value" (NASA 2011: 5). It was also meant to inform and influence lunar vehicle design and mission planning. The document's recommendations are "not legal requirements," however; "they are technical recommendations for consideration by interested entities" (NASA 2011: 6).

The NASA recommendations are the collective work of NASA's scientists and subject matter experts. They are followed in the document by rationales that are the explanatory comments and associated analysis supporting the recommendations. As a critical part of the document states, NASA (2011: 5) "has performed recent propellant/plume and lunar regolith impingement analyses and initiated a science evaluation that examined the risks and concerns of damage to the heritage Apollo landing sites resulting from future spacecraft descent/landing and associated surface and low-altitude flight mobility."

The technical guidelines are based in part on scientific observations, programmatic techniques, and records from several of the Apollo missions, especially Apollo 11 and 12. The Surveyor 3 spacecraft, even though it was in a crater under the main sheet of material blown from

the Apollo 12 lunar module, had significant "sand blasting and pitting from the Apollo landing" (NASA 2011: 13). Many of NASA's recommendations are made in terms of the trajectories of the descent/landing boundaries with a rationale for a "keep out zone" having a radius of 2.0 kilometers. A particular radius would vary as a function of the actual site being visited and the type of artifact(s) there, as well as its site location.

The NASA recommendations clearly define what a disturbance means in the context of future visits to lunar sites. The definition of *effect* parallels the National Historic Preservation Act and implementing regulations (36 C.F.R. 800 et seq.), which describes adverse effects. NASA (2011: 7) defines *disturbance* as "to effect a change or perturbation to the site artifacts resulting in loss of historic and scientific processes and information." These visits (from space tourists and other nations) could pose significant disturbance risks to these sites, thus potentially destroying irreplaceable historic, scientific, and educational artifacts and materials.

To reiterate, the definition of *adverse effect* in terms of federal preservation law (36 C.F.R. 800.5(a)(1)) is when "an undertaking may alter, directly or indirectly, any of the characteristics of a historic property that qualify the property for inclusion in the National Register in a manner that would diminish the integrity of the property's location, design, setting, materials, workmanship, feeling and association."

The difference between the concepts is that NASA's recommendations do not cite U.S. preservation law and regulations as applicable, and the document does not provide a framework for assessing the significance of all the U.S. lunar sites. The NASA recommendations do select two archaeological sites, Apollo 11 and 17, the first and last lunar landings, as the most significant and deserving of special treatment.

Federal preservation law defines the actions of the federal agency—the government entity that is doing an undertaking—as the one responsible for assessing the adverse actions of that undertaking and to mitigate those adverse effects by proposing and completing a particular plan of action, for example, completing a data recovery plan that may involve an archaeological excavation at the site. The site would essentially be destroyed, but through the scientific and professional

methods used to record it and the documentation of the information gained from any excavation and analyses, the site's information would be preserved. That data set created would be used to answer important questions about the past.

Because, in part, the NASA recommendations do not cite any existing federal preservation law and do not propose a framework for evaluating significant properties on the Moon, the only mitigation measures suggested are avoidance of actions near a given site that would harm or destroy that site.

A critical problem in defining the scope of the threats on the lunar surface is that new space-faring entities, whether commercial interests or from other nations, have not yet demonstrated and may not have the ability to maneuver their spacecraft to avoid the specified boundaries of either the sites or artifacts, or both (see chapter 7).

Given the acceleration of the use of space since the 1950s and new initiatives including space tourism in the twenty-first century, there are more nations and diverse commercial interests in space and other celestial bodies, especially the Moon. Early space sites were mostly created by two nations, the United States and the Soviet Union (USSR), with the support of their respective allies. Today the use of space is heavily commercialized and many more nations are involved. The remoteness and the costs of going to the Moon have prevented any major cultural impacts to the early lunar sites. With the exception of the Apollo 12 visit to the earlier Surveyor 3, there have been no revisits to any existing historic lunar site. This will probably not be the case in the next fifty to one hundred years.

Philip Stooke (2008) has proposed that at a minimum, until formal arrangements and agreements are made, all sites from what he calls "the first lunar exploration era" (1959–76) be considered important and not visited. He has also noted, in his extensive atlas of lunar exploration (Stooke 2007), that there are problems with finding the exact location of some of these early sites and artifacts. The first lunar exploration era contains the material culture of the main players of that era and the origins of all subsequent lunar spaceflight. Ironically, first sites by the new commercial and national players would probably also deserve evaluation. Many lunar sites can be put in the same category as other

"firsts" of any human undertakings, such as the earliest landfall of Europeans in the New World in the eleventh century, which occurred after another earlier "first"—the migration of the ancestors of today's indigenous people in North and South America approximately 25,000 years ago. Stooke (2008) calls the current era of visitation to the Moon (post-1976 to the present) "Moon 2.0."

The commercial rush to the Moon began at the turn of the twenty-first century with companies like Lunacorp and Transorbital. The biggest competition to get there began at the end of 2007 with the advent of Google's Lunar XPrize. Ironically, if successful the Google Lunar XPrize has the potential to both damage and destroy historic lunar sites as well as creating the first commercial lunar site (O'Leary 2009a: 825).

The XPrize website states that the mission of the Google Lunar XPrize is "to incentivize space entrepreneurs to create a new era of affordable access to the Moon and beyond" (Google 2015). The Google XPrize is described earlier in the book, but the rules and dates of completion have shifted since 2007 and will probably change over its history. As well as the main prize, a series of bonus prizes have been proposed. The prize purse will be US$30 million to teams who are able to land a privately funded rover on the lunar surface, travel 500 meters, and transmit high-definition video and images (Google 2015). The first team that is successful will be awarded US$20 million, and the second team to complete the mission gets US$5 million. There are various mission requirements such as landing requirements, mobility requirements, and broadcasts and uplinks. Payloads, provided by the XPrize, must be equal to 1 percent of the craft's mass and not less than 100 grams or more than 500 grams (Google 2015). Teams cannot receive more than 10 percent of their funding from a government. There are various milestone and bonus prizes, but the ones that are most relevant to space archaeology and heritage are the Apollo Heritage Bonus Prize and Heritage Bonus Prize:

- Apollo Heritage Bonus Prize—$4 million will be awarded to a team that can produce an Apollo Heritage Mooncast from the site of Apollo 11, 12, 14, 15, 16 or 17. The Mooncast must include

eight minutes of dynamic video in both high definition and lower resolution near real time video, a panoramic photo of the Apollo site, and an image showing a substantial portion of the craft from the heritage site.
- Heritage Bonus Prize—$1 million will be awarded to a team that can produce a Heritage Mooncast from a site of interest on the lunar surface, approved by the Judging Panel. The Mooncast must include eight minutes of dynamic video in both high definition and lower resolution near real time video, a panoramic of the heritage site, and an image showing a substantial portion of the craft from the heritage site. (Google 2015)

Requiring the teams to follow NASA's 2011 recommendations is not in the team requirements. A question posted on the Google XPrize website asked, "What are you doing to protect the hardware on the moon from previous lunar missions?" (Google 2015). It is interesting that the artifacts are referred to as "hardware" and there is no mention of lunar artifacts or sites. The response to the question states that all the teams are "expected to conduct their missions in a way that preserves humankind's legacy on the Moon." Those methods are not specified. A judging panel will approve each team's mission plans; however, the current panel does not appear to include a professional archaeologist, a historic preservationist, or anyone with related training or experience. Although the answer on the website does refer to the judges' approval of a mission plan that "will follow best practices for preserving lunar heritage," there are no descriptions of what those practices are. The website does state that it will include practices "published by NASA," referring to the 2011 NASA recommendations.

According to Justin St. P. Walsh (2012), several of the competing teams initially announced their plans to get the Heritage Bonus, and Astrobotic and Frednet, which is no longer in the competition, chose Tranquility Base. After NASA's recommendations were released in 2011, participants in the competition said they were canceling their plans to go to Tranquility Base (Walsh 2012). Currently both the Apollo Heritage Bonus and the Heritage Bonus remain as part of the Lunar XPrize,

however, and even a well-intentioned expedition to any historic lunar site could alter or adversely affect the material culture of space heritage.

The rhetoric of the Lunar XPrize is focused on competition. In one video, one of the Google Lunar XPrize participants refers to the moon as "a gas station in the sky" (Google 2015). This is the new era of commercial space and a new way to think about space and the Moon as a financial and prestigious prize that will go to the smartest and best entrepreneurs. This is a contest rather than a battle between superpowers in which space was perceived as a battlefield in the Cold War. The chairman and CEO of the XPrize Foundation, Peter Diamandis, is featured saying, "It is only with a commercial mindset and commercial technologies that we will achieve a long-term vision of space commercialization and industrialization" (Google 2015). Space is being taken out of the commons area for peaceful purposes and thrust into the world of global commerce.

As of 2015, there were sixteen competitive teams, with three from the United States and none from Russia, which currently has one of the only rockets that can transport crews to the International Space Station. The teams and their affiliation include the following: Agelicvm (Chile); Astrobiotic (United States); Euroluna (international); Hakuto (Japan); Independent-X (Malaysia); Team Indus (India); Team Italia (Italy); Moon Express (United States); Omega Envoy (United States); Part-Time Scientists (Germany); Plan B (Canada); Team Puli (Hungary); Team Spaceil (Israel); Spacemeta (Brazil); Stellar (international); and Synergy Moon (international) (Google 2015). There is a note that the ranks of the competitors have shrunk since the inception of the XPrize. There is little formal recognition of the need for any comprehensive international protocols or agreements for protection of space heritage, which may have large unintended consequences for the preservation of extraterrestrial space heritage. These actions, if left unchecked, will result in destruction of many important space heritage sites.

Since about 1958 and the early days of the space race, there have been both more material culture and more players in space in terms of exploration and commercial development. Spacecraft are or have been in orbit around the Moon, Mars, Venus, and Pluto. Several celestial

bodies have robotic craft on their surfaces, including the asteroids Eros and Itokawa and the comet Tempel 1 (Gold 2009). The Space Age took place at the same time as the decolonizing process after World War II, and until the fall of the USSR in 1991 national prestige was the main motivating force in the development of space programs (Gorman and O'Leary 2013: 417). The United States and the Soviet Union stamped all their missions with national symbols such as flags and gave their spacecraft vehicle names (Eagle, Mir). Even popular material culture (astronaut ice cream and the Swedish rock band the Spotnicks) are part of the early Space Age. The story of space history is visible and tangible in the cultural resources and exists as an incomplete bricolage of records for this amazing human endeavor (Gorman and O'Leary 2013).

Today, there are essentially no nations that do not depend on satellite-based navigation and telecommunications. Besides providing global services, the proliferation of space-based systems has created enormous amounts of what many call "space junk." Alice Gorman (2015: 43) writes that the junk can be differentiated into its component parts and not all of it is insignificant. There are opportunities for archaeologists to study "the dazzling complexity of the orbital assemblage" as a whole to understand the complexities of human behavior in the twentieth and twenty-first centuries (Gorman 2015: 43).

By 2008 more than fifty nation-states and organizations had satellites in orbit, and the number increases each year (Reed 2009: 965). Space services have become a commodity of the telecommunication age. Any nation or private or public agency can buy space-related services and even create its own space capabilities. Participation in international space markets is growing. Countries such as China, India, and Japan have space vehicles that range beyond low Earth orbit. In total, there are approximately forty-six space agencies in the world, which include international groups such as the United Nations' Office for Outer Space Affairs and the European Space Agency (Reed 2009). Several of the most prominent countries and their participation are discussed below; it is interesting that there have been no formal agreements or policy statements from or between any nations regarding space heritage.

The European Space Agency (ESA) had its beginnings in 1958 when France and Italy recommended that European governments set up a

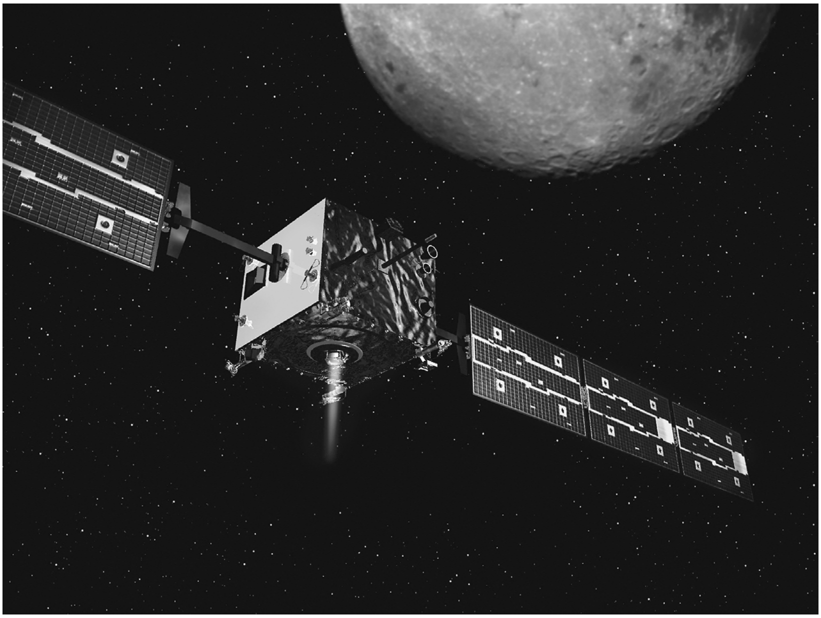

Figure 8.2. SMART-1 (photo courtesy of NASA).

joint organization for space research. In 2003, ESA launched SMART-1, a robotic probe that was used to test solar electric propulsion and other deep-space technologies, while performing scientific observations of the Moon. SMART-1 was the first ESA mission to the Moon (figure 8.2). Among the scientific investigations, mission data provided answers to questions about the origin of the Moon and ice in the craters at the Moon's South Pole. The mission ended in 2006 when the spacecraft, in a planned maneuver, struck the lunar surface in the Lacus Excellentiae region (European Space Agency 2015). By 2007, a European Space Policy had been signed by European Union member states, although the agreement does not address space heritage. By 2008 ESA had a laboratory on the International Space Station (Reed 2009).

The former USSR was a leader in space beginning in 1958 with the launch of Sputnik. Formed after the breakup of the USSR but using technology and launch sites of its predecessor, the Russian Federal Space Agency (RKA) has been a leader in providing satellite launches and space tourism. In 2005, it performed nearly 50 percent of all commercial satellite launches into space (Reed 2009). It is a partner in the

International Space Station (ISS) program and is the only agency to provide services to the ISS for fare-paying tourists. Since 2007 there have been five such tourists, paying around US$20 million each. RKA launches are currently the only way any astronauts can get to the ISS.

The Japan Aerospace Exploration Agency (JAXA) is Japan's national aerospace agency. It is responsible for the research, development, and launch of satellites into orbit and for missions to asteroids. It is the product of an earlier merger of various space partners in Japan, with its beginnings in one of those partners, the Institute of Space and Astronautical Science, in 1955 (Reed 2009). Another partner built the Japanese Experimental Module for the International Space Station and trained Japanese astronauts. Japan has explored the solar system. One spacecraft, Hayabusa, brought back a sample from a celestial body called a "sample return." Hayabusa was a probe to verify the practicality of acquiring technology developed to archive future full-scale sample return missions. Launched on May 9, 2003, it reached its target, the asteroid Itokawa, on September 12, 2005. In September and October of that year, it completed most of the remote sensing and measurement of the geometry of Itokawa, and it made two landings in November 2008 to collect samples. It returned to Earth in June 2010 with samples (Japan Aerospace Exploration Agency 2015).

Founded by Vikram Sarabhai, a visionary under Prime Minister Jawaharlal Nehru who insisted that space research be an important part of India's future in 1961, the Indian Space Research Organization (ISRO) is a major player in space. ISRO provides space hardware and services commercially and is part of the expanding market for launching payloads of other nations (Reed 2009). ISRO built India's first satellite, Aryabhata, which was launched by the Soviet Union in April 1975. In 1980, India's Rohini became the first satellite to be placed in orbit by an Indian-made launch vehicle.

Chandrayaan-1 was India's first mission to the Moon. The unmanned lunar exploration mission included a lunar orbiter and an impactor. ISRO launched the spacecraft in October 2008 from Sriharikota, India. The vehicle was successfully inserted into lunar orbit. It carried high-resolution remote-sensing equipment for visible, near-infrared, and soft and hard X-ray frequencies. During its 312-day operational

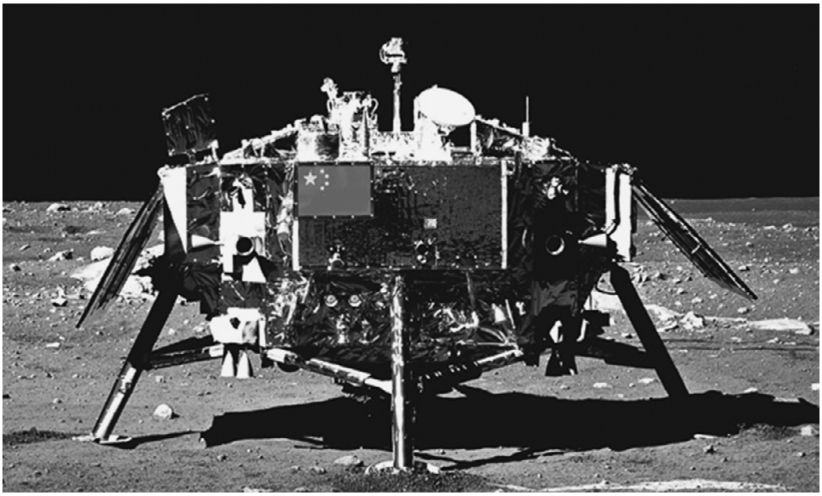

Figure 8.3. Chang'e 3 taken from Yutu rover on the lunar surface (photo courtesy of China National Space Administration).

period (two years had been planned), it surveyed the lunar surface to produce a complete map of the Moon's chemical characteristics and three-dimensional topography (ISRO 2015; National Space Society 2008). Chandrayaan-1's Moon impact probe was released and hit the lunar surface on November 2008 near the Moon's South Pole (NASA 2008b).

China has rapidly built up its space program since it first sent an astronaut into space in 2003. In 2013 the China National Space Administration sent the spacecraft Chang'e 3 (Moon Goddess) to the lunar surface on the Bay of Rainbows. Its rover, Yutu (Jade Rabbit), though unsuccessful in completing its longer mission, roved a short distance on the lunar surface. The rover carried ground-penetrating radar equipment to explore sediments that could be mined in the future (figure 8.3). The Moon exploration makes China one of only three nations—after the United States and the former Soviet Union—to "soft-land" on the moon's surface (Brown 2013). China's moon exploration program focuses on orbiting, landing, and returning to Earth. The China National Space Administration has plans to land on the far side of the Moon in 2020 (Brown 2013). It also has an active program to put its astronauts in space.

While many may say that the human return to space, revisits to the Moon, and visits to Mars are not going to happen in the near future, because of the risks and exorbitant cost, these activities will happen at some time in humanity's future. Robotics missions will most likely be selected first, because of costs (McNutt 2006). The increase in the number of nations, the quantity of satellites and spacecraft, and the increased amount of cultural material floating in space, especially in low Earth orbit, speaks to the need to evaluate and make cooperative international decisions about not only how space and celestial bodies are used but also why they should be preserved for future generations. Typically, the American public looks at historic preservation through the eyes of the National Park Service.

The idea for creating a series of public parks or reserves on the Moon was first proposed by P. J. Capelotti (2010). In *The Human Archaeology of Space: Lunar, Planetary and Interstellar Relics of Exploration,* he created an archaeological catalogue of artifacts and features left by the Apollo program on the lunar surface. He suggests that the Apollo program's "deposits can be arranged into five cohesive geographic areas on the near side of the Moon. The areas can be thought of as notional archaeological preserves, areas of the Moon specially demarcated in order to place the entire database (minus the artifacts yet to be located) under a protective regime that will shield them both from environmental deterioration and from the effects of future exploration, visitation and potential exploitation" (Capelotti 2010: 21).

Capelotti (2010) used the imagery obtained by NASA from the Lunar Reconnaissance Orbiter in 2009. The acquired imagery of the lunar surface has such an excellent degree of resolution that it can be used by space archaeologists for demarcating boundaries of objects and trails as well as proposed lunar archaeological preserves (figure 8.4).

However, the method or legal vehicle, either national or international, with which to create such areas is not specified. Capelotti (2010: 15–16) does state that cultural resource management of aerospace sites in extreme environments like those of the lunar Apollo sites "will likely be founded on many of the same principles that currently guide the attempts at stabilization, preservation, and study of historic sites in Antarctica" (see chapter 7).

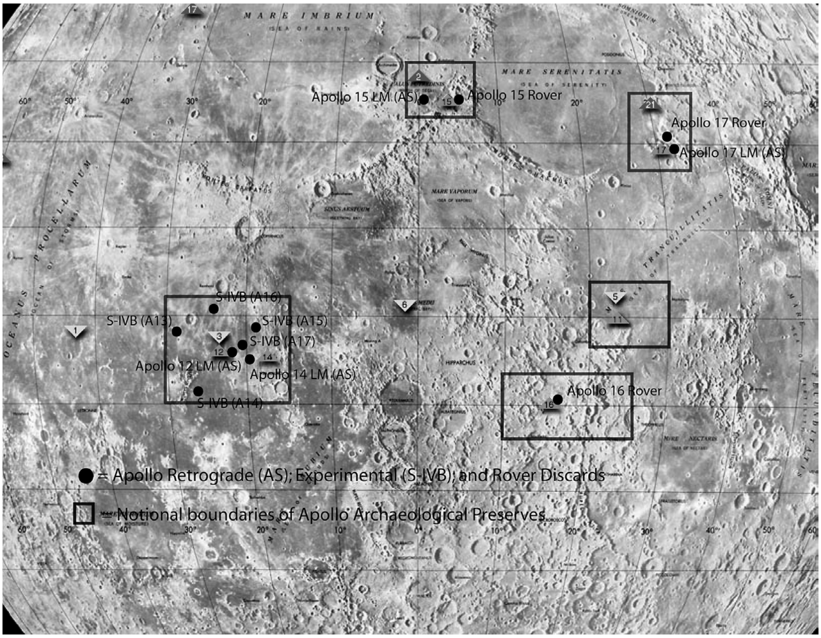

Figure 8.4. Boundaries of potential lunar preserves, based on the distribution of Apollo sites on the Moon (photo courtesy of P. J. Capelotti).

The Outer Space Treaty, ratified in 1967, specifies that those nations that place artifacts on the Moon retain ownership of them, while prohibiting title to the surface of the Moon. The Outer Space Treaty also emphasizes the importance of access to space and international peaceful cooperation (Hertzfeld and Pace 2013). The Outer Space Treaty does not address preservation issues at lunar sites that will be relevant when new players such as China land their astronauts on the Moon, nor does it address the Google Lunar XPrize competition for the first commercial venture to place robotics on the lunar surface (O'Leary 2015: 9).

Preservation efforts off Earth by individual U.S. states (such as California and New Mexico) are not binding in any legal sense to other states or the federal government, or by international law, although federal undertakings are subject to compliance with the National Historic Preservation Act. NASA's 2011 recommendations are just that: guidelines that seek methods to avoid damage to U.S. property on the Moon. Both efforts are critical in the evolution of space heritage in that they

recognize the historic and scientific value of the artifacts and sites from the earlier Space Age.

Another effort, although it had several flaws, was H.R. 2617, The Apollo Lunar Landing Legacy Act, introduced in the U.S. House of Representatives by two U.S. congresswomen—Donna F. Edwards of Maryland and Eddie Bernice Johnson of Texas—on July 8, 2013. It was referred to the Committee on Science, Space and Technology and the Committee on Natural Resources. The major actions to be taken by the bill were to establish as a unit of the National Park Service a park that incorporated all areas of the Moon "where astronauts and instruments connected to the Apollo program between 1969 and 1972 touched the lunar surface," as cited in H.R. 2617 Section 4(2). The purpose of the act was to "preserve and protect" the artifacts and sites for scientific investigation and the benefit of future generations and to improve the public's understanding of the Apollo program, as stated in H.R. 2617 Section 3(1–3). NASA would act as the administrator with the National Park Service under the auspices of the U.S. Department of the Interior. As stated in H.R. 2617 Section 8, after its creation, the United States "shall submit the Apollo 11 lunar landing site to the United Nations Educational, Scientific and Cultural Organization (UNESCO) for designation as a World Heritage Site" (U.S. House of Representatives 2013).

O'Leary previously stated, "I applaud the idea that two Congresswomen have decided to spark public dialogue about protecting the artifacts on the moon as an important part of American and ultimately, humanity's lunar legacy" (David 2013). While diplomatically phrased, the legal challenges to the bill mounted and exposed its flaws. Critics Michael J. Listner and George Robinson focused on the inherent flaw that the lunar surface is not part of U.S. territory and cannot be managed by the U.S. National Park Service or nominated to the World Heritage List (David 2013). H.R. 2617 fails to address the interests of other nations that have visited or will visit the Moon. Also, creating a national park would be perceived as a unilateral U.S. action to control parts of the Moon, and the establishment of a park could be interpreted as a declaration of territorial sovereignty (Hertzfeld and Pace 2013: 1049). The bill has been criticized for being in direct conflict with

international law and a violation by the United States of the Outer Space Treaty (Hertzfeld and Pace 2013). Although the bill specifies the artifacts that remain the property of the United States under the Outer Space Treaty, it does not deal with the issue of the lunar surface on which the artifacts rest. The Outer Space Treaty emphasizes the use of space by nations to benefit all peoples, but the U.S. National Park System Act was created for parks that benefit the people of the United States—a problem that does not promote international agreement. The process by which a site is submitted to UNESCO for consideration on the World Heritage List does not explicitly require the sites to be located within the territories of nations and states on Earth (Hertzfeld and Pace 2013; Westwood 2015).

One of the directions that space law experts suggest for space heritage preservation advocates to go is to gain international, not unilateral, recognition for the sites, which includes their physical location on the lunar surface and the archaeological assemblage (artifacts and features) at the site (Hertzfeld and Pace 2013). This means bilateral agreements between the United States and Russia, especially, the major players on the Moon. These nations both have assets on the Moon and have a common interest in the peaceful uses of outer space, which includes scientific research and cultural heritage management for the future (Hertzfeld and Pace 2013). Many nations, including Russia, the United States, and China, already cooperate in space programs. While the negotiated international agreements will be politically difficult, participants can at least agree that cultural preservation is needed and would help to protect humanity's record of being on another celestial body. Henry Hertzfeld and Scott Pace (2013) argue for direct negotiations at the highest level of government. Humanity's record would include the early lunar Russian sites. Other nations would be free to join the agreement if and when they have or have had the ability to go to the lunar surface (Hertzfeld and Pace 2013).

The most desired outcome that participants in space archaeology and heritage want (and have wanted for the past dozen years) is to create awareness of the issue of the value and importance of preserving humanity's exploration of space among the public at large. Also,

there is a critical need to determine how best to address the problem of preserving humanity's heritage in space. There exist ways to solve these problems. Reaching goals needs the commitment of both the public and those who have the experience and intention to see the process of preservation happen for future generations.

9

Preservation Works

Success Stories in Space History

If there is one great success for historic preservation of space heritage, it is the preservation of three space shuttle orbiters. The Space Transportation System (STS), better known as the Space Shuttle program, was established in the late 1960s to create reusable space vehicles that would enter space, return to Earth, and be prepared for another flight. Starting on April 12, 1981, with *Columbia*'s first flight, the space shuttle program finished with its last mission, STS-135, flown by *Atlantis,* in July 2011. In total, five shuttle orbiters were built for spaceflight, and they soon became icons of the U.S. space program. The first two, *Columbia* and *Challenger,* met tragic ends, but the remaining three, *Discovery, Atlantis,* and *Endeavour,* continued their epic service until retirement in 2011.

The retirement of the orbiters was considered a Section 106 process under the National Historic Preservation Act. Under strong encouragement from one of the authors of this book, Milford Wayne Donaldson, chairman of the Advisory Council on Historic Preservation (ACHP), NASA initiated consultation with ACHP and with the state historic preservation officers from the states that best represented NASA's major centers: Alabama, California, Florida, and Texas. *Discovery,* which had flown more missions than the remaining two, was documented according to the Historic American Engineering Record (HAER) along with modifications made to *Atlantis* and *Endeavour* over the years. These exciting narratives are now preserved and related in

various formats across the nation to a broad audience of space professionals, schoolchildren, and the general public. The orbiters are on display at the California Science Center in Los Angeles (*Endeavour*); Kennedy Space Center, Florida (*Atlantis*); and the Smithsonian Institution's National Air and Space Museum Udvar-Hazy Center, Virginia (*Discovery*) (ACHP 2012). Testing, assembly, maintenance, and launch facilities are being evaluated for potential new uses, but many are considered obsolete for NASA's ongoing missions and are slated for demolition. Early NASA sites that have been razed include the Launch Complex 34 Engineering Support Building at Kennedy Space Center and the Mission Control Center at Cape Canaveral Air Force Station (ACHP 2006).

If there is one "flagship" for the history of human spaceflight, it is Tranquility Base on the Moon, the site of the first human lunar landing, on July 20, 1969, by Neil Armstrong and Buzz Aldrin. The idea for nominating Tranquility Base for inclusion on the California Register of Historical Resources (CRHR) grew out of classroom discussions between Lisa Westwood and her undergraduate anthropology students at California State University–Chico and Butte Community College. Tranquility Base was used as a case study to illustrate the universal importance of the Apollo 11 landing site and noted how the National Register did not expressly prohibit listing because of either age or location. This precipitated a draft nomination of Tranquility Base to the National Register in the fall of 2009 (Westwood et al. 2009).

The initial nomination to the National Register received mixed reactions, and after consultation with NASA, the National Park Service, and Milford Wayne Donaldson, the California SHPO at the time, the decision was made to withdraw the National Register nomination and instead advance a nomination to the CRHR. Westwood, Beth Laura O'Leary, and two former New Mexico State students, Ralph Gibson and John Versluis, collaborated on a CRHR nomination that spoke to the strong ties that Tranquility Base has to the state of California (many of which are profiled in this book). In recognition of the international treaties that prohibit ownership or jurisdiction over the lunar surface or subsurface, only the 106 objects and structures at Tranquility Base were included in the nomination.

The reaction to the nomination to the CRHR prompted high-level discussions in the state, including questions of the legality of nominating a resource not located in California to the CRHR. Further review of the criteria for inclusion in the CRHR by state attorneys confirmed that a historical resource need not be physically located within the political boundaries of the state of California to be listed and that the resource need only be associated with the state—a fact that could not be refuted. Moreover, the state's attorneys concurred with the position that state environmental laws that require nonfederal agencies to consider the effects of projects on state-listed or eligible resources do not apply to the Moon, because the State of California has no jurisdiction over it. The listing of Tranquility Base on the CRHR was determined to be symbolic (Donaldson 2010).

Still, that symbolic action was bolstered by support from historic preservation officials and professionals across the country. Strong letters of support were received from New Mexico state historic preservation officer Jan Biella, Oklahoma state historic preservation officer Bob Blackburn, and California state historic preservation officer Milford Wayne Donaldson. NASA issued a letter stating "no opinion" on the listing of the site on the CRHR (Norwood 2010).

On January 29, 2010, Westwood and Gibson, whose master's thesis in anthropology was on space heritage preservation, presented the nomination to California's State Historical Resources Commission for approval of the listing. After much deliberation, the commission unanimously voted to list Tranquility Base on the CRHR; the vote made this the first cultural resource not located on Earth to be listed on a historical registry anywhere.

The idea for nominating the objects and structures at Tranquility Base (now designated as Laboratory of Anthropology [LA] site number 2,000,000) to New Mexico's State Register of Cultural Properties in April 2010 came about after two events occurred. The first was when a group of cultural resource management students with Beth Laura O'Leary, of the Department of Anthropology at New Mexico State University, in 2006 decided to archaeologically record the Tranquility Base site and ask to put the site on the state's Historic Preservation Division's archaeological database in the Laboratory of Anthropology. Working

with then-director William Doleman, the group completed a description of the lunar landing site on a Laboratory of Anthropology form—called an LA form. This lunar site description followed the protocol for all listed archaeological sites in the database with location, setting, and quantity of artifacts and features including topographic site and locational maps. The New Mexico Cultural Resource Information System is the database for recorded prehistoric and historic sites within the state. Both then–New Mexico state historic preservation officer Katherine Slick and William Doleman took a dramatic step in 2006 when they agreed to put the first lunar site in the largest archaeological state database in the country as LA 2,000,000. The one qualification that was a challenge to meet was that the sites all be within the state of New Mexico. This problem was solved by the consent of the New Mexico Museum of Space History director, Mark Santiago, in Alamogordo. As the director at that time, he allowed LA 2,000,000 to be directly connected to the museum.

The State of New Mexico agreed to recognize the Apollo 11 Tranquility Base site on the Moon as a historic archaeological site as part of their database in the Laboratory of Anthropology in Santa Fe. A marker was placed at the New Mexico Museum of Space History in Alamogordo on Saturday, May 6, 2006, commemorating the July 20, 1969 landing on the Moon as LA 2,000,000.

LA 2,000,000 represents the site on the Moon, with the New Mexico Museum of Space History serving as its host on Earth. The location of this marker at the museum at UTM Coordinates Zone 13 E413969/N3642735 will be linked forever to Lunar Coordinates 0.67266 degrees N latitude 23.47298 degrees E longitude, the first human landing site on the Moon. This action made New Mexico the first state to recognize the significance of the historic archaeological assemblage and international heritage status of Tranquility Base on the Moon (New Mexico Museum of Space History 2015b). It also marked the first effort by a state to preserve the cultural heritage of the Moon (O'Leary 2009b).

The other event that spurred the nomination of Tranquility Base to the New Mexico Register of Cultural Properties was a direct outcome of the Lunar Legacy Project. The project was funded in 1999 by the New Mexico Space Grant Consortium, an educational outreach program

of NASA, at New Mexico State University. Two students, Ralph Gibson and John Versluis, who were respectively in the anthropology and history graduate programs at the time, with their advisors Beth Laura O'Leary and Jon Hunner (public history), applied for and were granted monies to describe the archaeological assemblage at the Apollo 11 lunar landing site. The Lunar Legacy Project was also concerned with the application of U.S. federal preservation law to preserve the site. One of the clear legal problems with the Moon's cultural resources is that by the Outer Space Treaty, no one owns the surface of the Moon, although the materials belong to and are the responsibility of the nation that put them there (O'Leary 2009a).

In 2001, the Lunar Legacy Project approached both the federal agency, NASA, and the federal preservation authority, the Keeper of the National Register of Historic Places (NRHP), by proposing that the lunar site become a National Historic Landmark. As previously described in chapter 7, although the response from NASA's deputy counsel and the Keeper of the NRHP was not encouraging, this action did bring the issue to the attention of the U.S. preservation authorities. The coordinated responses made it clear that both felt that designating the lunar site a National Historic Landmark would be considered a claim of sovereignty over a location in space, not allowed by the Outer Space Treaty, and would be viewed by the international community as a claim over the Moon (O'Leary 2009c). Additionally, the Keeper of the NRHP indicated that it would not be appropriate for her to designate any landmark on the Moon and that her office did not have sufficient jurisdiction or authority over the Moon (O'Leary 2009c). These events illustrate the complexities for lunar sites that supersede the disposition and preservation of sites on Earth. The need became more urgent when in 2007 Google initiated the Lunar XPrize, with its Apollo Heritage Bonus Prize and Heritage Bonus Prize. There is a definite hole in the preservation fence. The decision to request individual state-level efforts was a reaction to the lack of commitment at the federal level.

As with Westwood's work with students, at the beginning of the spring semester in 2010 O'Leary's graduate Cultural Resource Management Seminar students at New Mexico State University decided to write the State Register of Cultural Properties nomination for New

Mexico (O'Leary et al. 2010). State law in New Mexico does not require in statute that the property nominated be in New Mexico, only that the property must be relevant to the culture and history of New Mexico. In April 2010, the New Mexico Cultural Properties Review Committee unanimously voted to place the objects and structures on the State Register.

California and New Mexico were both found to have a long-standing historical relationship to the U.S. space program. The idea was to link the relevance of each state's history to those objects left on the Moon by the Apollo 11 crew. Many historic links to the site were found in New Mexico, beginning with the work done on the V-2 rocket by Wernher von Braun at White Sands Missile Range immediately after World War II and extending to New Mexico's plan to build a spaceport for commercial spacecraft.

The responses to both the California nomination and the New Mexico nomination made national press. The idea of putting the artifacts at the site on the Moon in a historic preservation framework at the state level was questioned, particularly in relation to how far the responsibilities and jurisdiction of California and New Mexico state preservation laws could stretch, but the idea of each state stepping forward to recognize the importance of the cultural resources on the Moon through listing them on their respective registers was overwhelmingly applauded. There has never been any real debate about those artifacts being valuable and significant; rather, the debate is on how to preserve them. The actions by California and New Mexico played a role later in NASA's decision to issue guidelines in 2011. Roger Launius at the Smithsonian Air and Space Museum and Beth Laura O'Leary were the only two historic preservation experts invited by NASA to help in creating their guidelines.

Other states, such as Florida, Virginia, Alabama, and Pennsylvania, as well as Puerto Rico, have likewise expressed interest in putting Tranquility Base on their respective registers of historic places. The Apollo program enlisted around 60,000 people during the time it was active. Literally all states from Alabama to Alaska participated in some way in the creation of ideas, prototypes, testing, and facilities for the Apollo program. Each state can demonstrate a historical relationship

and relevance to the quest for the first lunar landing. However, not all states maintain separate state historic registers; some use the National Register of Historic Places to inventory their cultural properties. Texas, which already has several space-related sites on the National Register of Historic Places—such as the National Historic Landmark Mission Control in Houston, Texas, was the only state to formally decline participation, when the state attorney general interpreted Texas state preservation law to include properties only physically located in the state of Texas. The efforts by California and New Mexico to list Tranquility Base were intended to raise public consciousness. The hope is that these grassroots attempts will influence decisions to make the site a U.S. National Historic Landmark that could eventually be placed on UNESCO's World Heritage List (O'Leary 2015; Westwood 2015). The significance of the site extends beyond individual U.S. states or the federal government. Tranquility Base exhibits "outstanding universal value," meeting five of the six criteria for inclusion in the World Heritage List (Westwood 2015: 146).

The other factor that has spurred both awareness and effort to protect the first lunar landing site is the passage of time. There were 60 million people on Earth who either listened to or watched the two astronauts, Armstrong and Aldrin, set foot on the lunar surface on July 20, 1969. The fiftieth anniversary is approaching in 2019, a half-century mark that often signifies personal and public recognition: it is a requisite length of time for being placed on the National Register of Historic Places, except when the property is younger and is of "exceptional significance"; and it seems to mark a chronometric human boundary of being "historic." Also, the death in 2012 of Apollo 11 astronaut Neal Armstrong, who was for all purposes an icon and a hero of the quest for the Moon, served as a reminder for everyone who was a witness that day when he stepped on the surface of the Moon. To many of us, he represents one of the most extraordinary events in the history of humankind.

Similar to the way the event of landing on the Moon was pronounced as a giant leap for mankind, so too does the burden for preserving significant sites associated with the Apollo program fall on many shoulders. It falls on all nations involved, and because almost every state in

the United States had a part to play, a multistate effort in space heritage preservation is warranted.

The notion of multistate historical nominations is not new. The establishment of the Manhattan Project National Historic Park in late 2014 may serve as a model for future efforts regarding space heritage on Earth.

The dropping of the atomic bomb on Hiroshima, Japan, on August 6, 1945, at the end of World War II, is often regarded as one of the most dramatic and tragic events of World War II and the twentieth century. Made possible by the Manhattan Project, that event, although at great cost to the Japanese, not only helped to end the war but also ushered in the atomic age that would determine how the next war, the Cold War, would be fought (Department of Energy 2015).

The Manhattan Project utilized a network of facilities primarily located at Los Alamos, New Mexico; Hanford, Washington; and Oak Ridge, Tennessee. Other places, even outside the United States, were also associated with the research, processing, development, and testing of the atomic bomb. The Manhattan Project was also responsible for gathering intelligence on the German nuclear weapon project, known as Operation Alsos. At its peak, the Manhattan Project employed 130,000 workers, and by the end of the war, it accounted for $2.2 billion in spending (Gosling 2010).

Recognizing the important historical significance of the Manhattan Project, the Department of Energy (DOE) took the lead in developing this multistate national park, as it did in the development of the Manhattan Project decades earlier. In the 1990s, the DOE developed a list of eight Manhattan Project sites—each barely old enough to meet the standard fifty-year threshold for "historic" status under the NRHP—to thoroughly document the project and preserve and interpret, in situ, the historically significant physical properties and artifacts from the Manhattan Project era. In 2011, the DOE joined with the Department of the Interior in the recommendation of the Manhattan Project National Historic Park.

In December 2014, Congress passed the National Defense Authorization Act of 2015, which designated a single park composed of the three sites in New Mexico, Washington, and Tennessee, resulting in a

discontiguous park under the management of the National Park Service. On December 19, 2014, President Obama signed the act into law, and on November 10, 2015, Secretary of the Interior Sally Jewell and Secretary of Energy Ernest Moniz signed the memorandum of agreement (MOA) between the two agencies to create and manage the park. The MOA included provisions for enhanced public access, management, interpretation, and historic preservation. With this signing, the Manhattan Project National Historic Park was officially established (Department of Energy 2015). The Manhattan Project National Historic Park is a good exemplary model for preserving the legacy of the Apollo program, which similarly is recognized as a discontiguous multistate arrangement of space heritage sites.

As discussed above, not all states have historical registries that can accommodate resources not physically located within that state's political boundaries, and therefore, other mechanisms of recognizing the significance of Tranquility Base are available. In 2013, following the issuance of the NASA guidelines, one of its main authors, Rob Kelso, a former NASA employee now with the Pacific International Center for Exploration Systems (PICES), based in Hawaii, worked toward recognition of the Apollo 11 site. There was mutual interest among PICES and members of Hawaii's legislature to formally recognize Hawaii's role in Tranquility Base. Subsequently, PICES, O'Leary, Westwood, and Donaldson teamed up to pursue a state-level nomination. O'Leary and Westwood traveled to Honolulu to meet with representatives of the Historic Preservation Office and the Historic Hawaii Foundation and, at the state capitol, with State Representatives Angus McKelvey, Mark Nakashima, Richard Onishi, Cindy Evans, Isaac Choy, and Clift Tsuji, as well as State Senator Will Espero. The support for formal recognition on the part of the State of Hawaiʻi was unanimous among the legislators. However, because Hawaii's state register can only accommodate resources that lie within the political boundaries of the state, the Moon would be excluded, and the decision was made to seek passage of a resolution by the state legislature. With important support from PICES and under the sponsorship of Representative McKelvey, Westwood and O'Leary drafted a resolution for consideration. On April 21, 2014, the legislature unanimously passed Resolution SCR 82, which

commemorated Hawaii's role in the Apollo 11 mission and designated July 20, 2014, as Tranquility Base Day in the state of Hawaii. Like the listings on the California and New Mexico state registers, Hawaii's recognition of the importance of Tranquility Base is essentially symbolic but nevertheless an outstanding example of a means by which the importance of historic preservation of space heritage can be recognised. A similar effort is currently in consideration by the State of Oklahoma.

Not all historic preservation efforts need to be initiated at the government level, however. In 2015, the National Air and Space Museum launched its first-ever Kickstarter campaign to use the concept of public crowdfunding to conserve, digitize, and display Neil Armstrong's Apollo 11 spacesuit in advance of its incorporation into a new exhibit called Destination Moon, scheduled to open in 2019 or 2020 (National Air and Space Museum 2015). The "Reboot the Suit" Kickstarter campaign allowed members of the public to donate funds online to meet an initial goal of $500,000. The campaign was so well received that it quickly exceeded its goal; as of November 2015, almost $720,000 from 9,477 donors had been raised, exceeding the optimistic revised goal of $700,000. The success of this campaign speaks to the public's desire to preserve important reflections and material culture of American space history and is an excellent model for funding preservation of facilities.

Most of us would think that an endeavor as closely scripted, planned, and recorded as the first lunar landing would have little room for souvenirs. A few months after Neil Armstrong died in 2012, however, his widow found a bag of artifacts left in the closet by her husband (figure 9.1). She contacted Alan Needell, curator of the Apollo collections at the Smithsonian National Air and Space Museum, because she thought they might have come from a spacecraft (Needell 2015).

The bag was a McDivitt Purse, made of plain white cloth, reminiscent of a 1950s ladies handbag. It had been stored on the lunar module during the Apollo 11 launch and was fitted to sit on the commander's station to the left of the hatch. The purse was meant for temporary storage but sat filled with artifacts that Armstrong kept as his own personal archaeological collection until his death forty-five years after the lunar landing. We all have our own kinds of personal archaeological collections in the back of the closet. Our own lives submit to archaeology, but

Figure 9.1. McDivitt purse, similar to one from Armstrong's personal collection (photo by Diane Penland, Smithsonian Air and Space Museum [NASM 2014-05230]).

most of our personal collections never include things that went to the Moon.

Experts determined that almost all of the artifacts from the McDivitt Purse were from the Eagle but at the time were formally scheduled to be left behind on the lunar surface when Armstrong and Aldrin reconnected with Michael Collins in the command module. The purse is even documented by Apollo Mission Control transcripts, when Armstrong says to Collins, "That one's just a bunch of trash that we want to take back." Later it would be described as "10 pounds of LM miscellaneous equipment" (Needell 2015). Its weight for the return trajectory may have been one of its more critical attributes, rather than what it contained.

Neil Armstrong's artifacts must have been significant to him, or he would not have kept them. They also happen to be important to the history of space exploration and have now been accessioned as part of the Air and Space Museum after being received from Carol Armstrong. The Smithsonian considers them so important that two are on display as part of the "Outside the Spacecraft: 50 Years of Extra-vehicular Activity" exhibit. One artifact is the 16mm data acquisition camera that was mounted on the window of the lunar module Eagle to record the landing. It appears pretty primitive compared to today's cameras (figure 9.2).

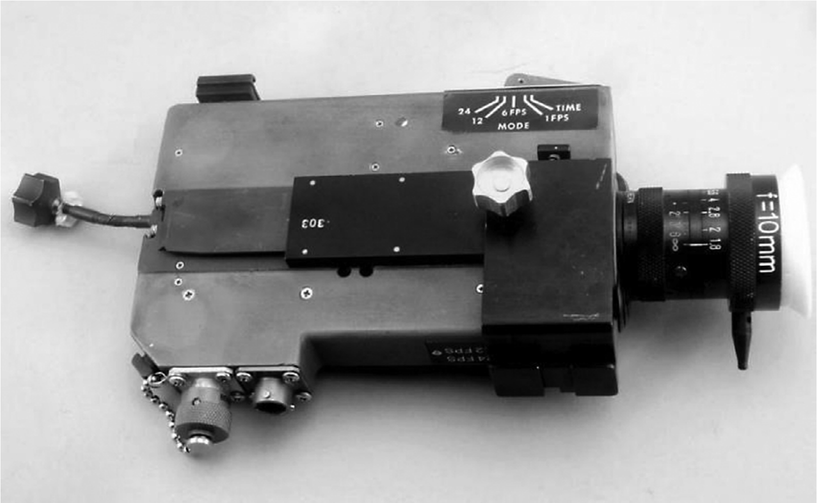

Figure 9.2. 16mm data acquisition camera (photo by Diane Penland, Smithsonian Air and Space Museum [NASM 2014-05229]).

The second is one of the two waist tethers from the lunar module for securing the astronauts, if they had to spacewalk from the lunar module back to the command module, in the event of a problem reconnecting the two spacecraft in orbit around the Moon (figure 9.3). The tether in Armstrong's personal collection was one that he used to support his feet during the one rest period on the lunar surface (Needell 2015). It is hard for most of us not to think of that simple rope as his lifeline; it is fitting that this prosaic tool was used to take him safely to the Moon and back.

Technically, all of these artifacts belong to the U.S. government, but there was never any discussion of theft of federal property when the objects were found. NASA took thousands of images from its multiple cameras, and it would not be a stretch to suggest that most people believe that Armstrong should be entitled to keep a camera that would have otherwise ended up abandoned on the remote lunar surface. In this case, NASA could not begrudge a few souvenirs kept by a man who risked so much to achieve an extraordinary goal and left them carefully packed up in the back of the closet where they would eventually be found. In a real sense, the purse and its contents were a small loan

during Armstrong's lifetime. Having resided with Armstrong continually since their use, they take on a more powerful and reverent meaning and, in some ways, are more historically significant than had they been in someone else's care.

Methods of historic preservation can also take advantage of modern technology—much of which was developed over a generation of research and development in the space industry. The use of laser scanning technology has been gaining momentum in recent years. In 2014, the U.S. Air Force's Forty-Fifth Space Wing at Patrick Air Force Base, Florida, partnered with the Alliance for Integrated Spatial Technologies at the University of South Florida (USF) to use terrestrial (tripod-mounted) laser scanning to create a detailed 3D replica of the pad of Launch Complexes 14 and 34 at Cape Canaveral Air Force Station (figure 9.4).

Figure 9.3. Waist tether (photo courtesy of Smithsonian Air and Space Museum).

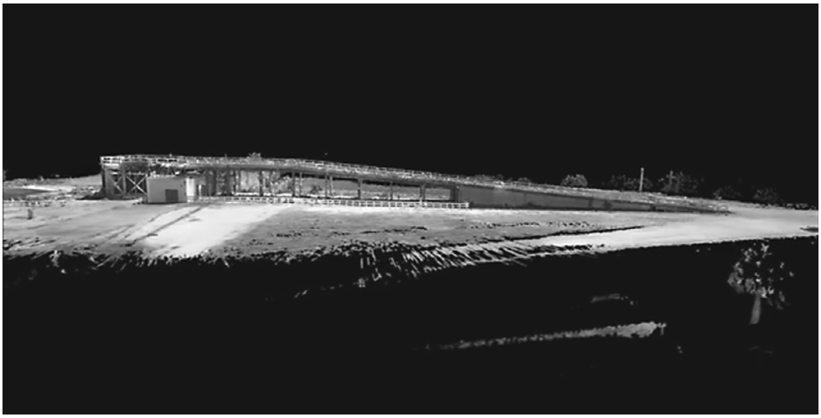

Figure 9.4. Launch Complex 14 digital replica produced by laser scanning (photo courtesy of University of South Florida).

Lori Collins, codirector of the Alliance for Integrated Spatial Technologies program, stated that "digital documentation will, in this case, not only be used for preservation and archival recording efforts, but for visualization through online, classroom and other applications, promoting education and outreach. Already, data from this project has been used in courses at USF on heritage preservation, museum visualizations and field method applications, and much more is planned in the way of teaching and training using heritage as a theme" (quoted in Schneider 2014). Another important application of this technology is the documentation of facilities that must be demolished, either because of safety concerns or, as a last resort, to accommodate important mission objectives.

As the previous success stories illustrate, there is clearly a national desire to preserve important pieces of our space history, and while the appropriate mechanisms for doing so were not tested or discussed until recently, these success stories frame the work that lies ahead.

10

Looking Ahead

There are many protocols for protecting heritage on Earth, and governments have instituted sanctions against looting and the destruction of their sites and export of their heritage. Looting of sites to provide collectors with valuable art and artifacts is an enormous threat to the study of humanity's past. The illicit art market is seen to constitute the third-largest international black market, after arms and drugs (Walsh 2012). One usually does not think of scientific and technological artifacts as being valuable as cultural goods and commodities, but Italy's Law 1089 of 1939, which was a model for other legislation defining newly discovered *beni culturali* (cultural goods) as the property of the state, was revised in 1999 to add "technical and scientific instruments" to the list of cultural goods (Walsh 2012: 238). Space objects have an ongoing market. The Internet provides a global marketplace. One example of an interesting sale is a small pin flag used on the Moon as part of the personal gear of an Apollo 16 astronaut, Charles Duncan, who is legally permitted to sell it (figure 10.1). It was auctioned online in January 2010 for $16,000 (in US dollars) (O'Leary 2015: 9). The value of the objects still on the Moon would be enormous.

Many nations object to the export of their cultural heritage to citizens and museums of more powerful, wealthier nations. UNESCO's Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transport of Ownership of Cultural Property was created to address this problem and has been an important international protocol, among others, on the subject of Earth's cultural heritage. This convention defined cultural property as designated by each

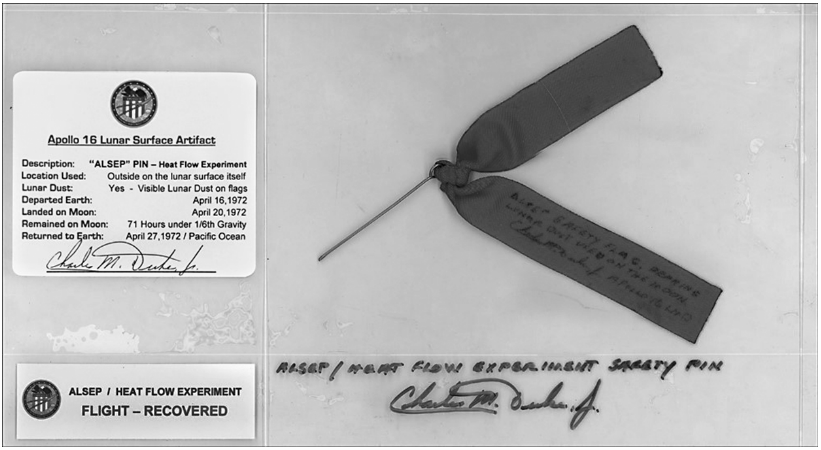

Figure 10.1. ALSEP pin flag, an auctioned lunar surface artifact from Apollo 16 (photo courtesy of Castel V. Ortiz Collection).

state to include those that were scientifically important—important to the history of science and scientists (Walsh 2012: 238–39). This 1970 treaty was joined in 1972 by the World Heritage Convention, which is fundamental to the management of humanity's heritage. While it focuses on sites and architecture, the 1972 Convention includes sites that "are of outstanding universal value from the point of view of history, art or science" (UNESCO 2013a). As discussed in chapter 6, the World Heritage Convention has a series of criteria for sites that can be eligible for the World Heritage List. It makes individual nations responsible for practicing protective measures that would maintain sites put on the list by a committee that determines which sites are to be included on the World Heritage List. The World Heritage Committee also can designate sites that are threatened by neglect, looting, natural disaster, or war (UNESCO 2013b). As Justin St. P. Walsh (2012) points out, what is useful in using the definition of significant cultural property by UNESCO's Convention is that this is a definition that has been agreed to internationally. The benefits of including properties on the World Heritage List are not just symbolic but supported by the state parties, providing technical assistance, training, and emergency assistance as well as funding. Other benefits include raising public awareness, increasing tourism, and gaining academic attention (Westwood 2015).

One of the problems of using UNESCO's World Heritage List is that in the United States only a site that is designated as a National Historic Landmark can be considered as a World Heritage site, through a competitive process determined by the consensus of the U.S. national committee that recommends it to UNESCO for listing. Early efforts reveal that both NASA and the Keeper of the National Register of Historic Places, which also oversees National Historic Landmarks, did not see themselves as having jurisdiction over the Tranquility Base lunar site and remarked that U.S. federal preservation law does not apply on the Moon. Harry Butowsky reported that during his study for the Man in Space series, elements on the Moon were not to be considered for listing on the National Register of Historic Places, because of international law regarding ownership and because the National Historic Landmarks need to be site-specific.

Ironically, the presence of the first human footprints preserved on Earth (at Laetoli, Tanzania) are listed on the World Heritage List. The first footprint on another celestial body "rises to the same level of significance" but is not considered (Westwood 2015: 135). Unfortunately, at this time, because of the required process, Tranquility Base cannot be listed, but protocols and processes can change. The change in NASA's commitment to preservation from the initial rebuff in 2000 to the issuance of guidelines in 2011 illustrates the agency's change of heart.

The Law of the Sea, the Antarctic Treaty, and the 1972 World Heritage Convention (discussed in chapters 6, 7, and 8) are useful because of the way in which they are involved in preserving extraterritorial cultural heritage. Space is not within any nation's territorial boundaries, and the relevance of other international historical agreements and their relevance cannot be overstated. Most of the focus on the threat to space heritage has been on the commercial exploitation of space and planetary protection, rather than on the history of preservation of heritage (Walsh 2012). Following the examples of existing agreements that are international, that concern places like marine and Antarctic environments that are difficult to reach, and that have as their primary actors nations, with the major purpose of scientific research, helps clarify the direction for future agreements and management of space heritage. A preservation structure for space and other celestial bodies should be

based on existing principles in historic preservation. This area of investigation is critical to solving the problem of mitigating future impacts to significant sites in space and on other celestial bodies.

Although no current international framework exists to protect significant cultural resources in space, there are clear precedents in existing law and agreements to develop a framework for the future. Future space missions can take into account planning and postoperational phases of their missions; the last phase of a mission or "end of life" decommissioning should include preservation alternatives in a plan as it directly affects the material evidence (Rogers and Darrin 2009: 803).

Stephen Doyle (2009) has suggested a direction for nations that wish to assume leadership in the preservation of space heritage. With the United States as the main actor, he suggests that to spur the Committee on the Peaceful Uses of Outer Space to consider space heritage, there should be first an approach to the U.S. State Department. Doyle (2009) argues that relevant proposals should come from the professions of archaeologists and historic preservationists. A working group of professionals would have a series of international workshops that determine the proper pathways and how to prepare preliminary proposals. Useful and credible proposals to national governments and expert advisors (other nations could have their own working groups in interaction and cooperation with the United States) would be followed by a request that these proposals be forwarded to the appropriate international officials (Doyle 2009). If the commitment to space heritage is matched with the endurance and drive to create a meaningful and substantive discussion of a course of action, then this could lead to international actions that encourage and finally facilitate preservation.

Equally important is recognizing that there are sites on Earth that are currently in use that are not viewed as historically significant but that these sites possess the capacity to eventually achieve significance. One example is the Kodiak Launch Complex, a commercial rocket launch facility for suborbital and orbital space launch vehicles located on Kodiak Island, Alaska. Alaska Aerospace Corporation owns and operates the complex. The launch facility opened in 1998 and has handled sixteen launches, most for the U.S. government. The first orbital launch from the Kodiak Launch Complex was an Athena I rocket on

September 30, 2001, which carried out the Kodiak Star mission for NASA and the Space Test Program, launching Starshine 3, Sapphire, PCSat, and PICOSatS. After a launch failure in August 2014, Alaska Aerospace planned to repair and upgrade the facilities to support larger rockets, but Alaska Governor Bill Walker stopped that work in December 2014 citing a state budget shortfall. The Kodiak spaceport has two launch pads with a mission control center with sixty-four workstations with high-speed communications and data links. There is a clean room for preparing satellites for launch, a fully enclosed seventeen-story-tall rocket assembly building, and two independent range and telemetry systems. The complex sits on 3,700 acres of state-owned land. Launch pad 1 is designed for orbital launches, while launch pad 2 is intended for suborbital flights. Forward thinking is critical to have preservation mechanisms in place now to deal with aging sites that may eventually be recognized as historically important.

Few would argue that facilities like the Apollo launch pads at Launch Complex 39, the vehicle assembly building, the crawler and crawler way, and the launch clock and flagpole at Cape Canaveral deserve preservation. No one disagrees with the need to preserve Mission Control in Houston; in fact, as of 2016, NASA is consulting with the Advisory Council on Historic Preservation on a programmatic agreement regarding its restoration. These are all clearly in the top echelon of space history facilities that are recognized globally as being important. However, ancillary structures, like the Kodiak Launch Complex and some of those highlighted in this book, are not often afforded the same visibility and considerations. The demolition of the last remaining historic Saturn V Launch Umbilical Tower in 2004 is just one example (see Launius 2011). The rate of loss of space heritage sites is increasing, despite the emergence of public preservation advocacy groups like Save the LUT and Save Hangar One. Federal agencies like NASA must develop priority lists of preservation strategies, mitigation plans, or long-term management plans that carefully balance the need for historic preservation with ongoing missions.

NASA, the U.S. Air Force, the U.S. Navy, the U.S. Army, and many associated entities originally connected with the Apollo program continue to invent and exploit new technology and to advance scientific

and engineering knowledge with extended space programs. Many of these postmission sites, facilities, and structures that were significant in the early history of science and technology are now inactive, have been deemed obsolete and have been destroyed, or simply have been lost through lack of adequate maintenance or neglect.

Although the number of properties formally recognized through the Man in Space Historic Landmark Theme studies by the National Park Service as significant for historic scientific and technological achievements was small in the late 1980s, the number of historically significant scientific properties is actually quite large when viewed through the perspective of the processes and criteria of the National Historic Preservation Act.

As we stay on the cutting edge of technology in space exploration and discovery, many of the facilities and much of the equipment associated with these advancements remain in active use today, and many have been or need to be upgraded or heavily modified and await continuous changes. However, the appropriate role of historic preservation in the decision-making process is generally lacking in the management of these facilities. Adding to this dilemma is the existence of hundreds of private institutions that received federal support through research grants for these technological advancements but are generally absent from any oversight to preserve the facilities and objects.

The rapid technological changes in twenty-first-century space exploration and discovery by established institutions, along with the introduction of private companies interested in exploiting space travel and "heritage" tourism, take on increased importance. Both federal agencies and private companies are obligated to present and future generations to consider the effects of their actions on the historic values embodied in selected facilities.

As we move forward in protecting our history through the preservation of these space-related resources, it is not sufficient to leave only memories, perceptions, or expressions captured in an obscure report filed away from public recognition. Tangible assets of the space exploration era, albeit difficult to reuse but nonetheless significant, must be preserved as icons for what they can teach us and future generations about a very special period during the nation's and the world's history,

when we both faced the threat of nuclear holocaust and celebrated the incredible achievement of putting a human being on another celestial body. To do this, we must preserve the extraordinary cultural resources of the space exploration period for generations to come (Donaldson 2012b). As Butowsky told Milford Wayne Donaldson in 2016, "We have the engineering and technological knowledge to go to the Moon, the planets, and anywhere we want to go in the solar system but lack the common sense to preserve and interpret this technology for this and subsequent generations of the American people. The destruction of these resources will leave us historically ignorant about the space program."

In President Barack Obama's State of the Union address in January 2016, he challenged the country to aim higher, pointing to successes of the past. He said, "In fact, many of our best corporate citizens are also our most creative. This brings me to the second big question we have to answer as a country: how do we reignite that spirit of innovation to meet our biggest challenges? Sixty years ago, when the Russians beat us into space, we didn't deny Sputnik was up there. We didn't argue about the science, or shrink our research and development budget. We built a space program almost overnight, and twelve years later, we were walking on the moon."

Preservation of our heritage is also one of our nation's greatest achievements. President Obama said that the "spirit of discovery is in our DNA," and as proponents of preserving the exploration of space and all the achievements before it, we agree.

Humanity has crossed many frontiers in its history. The ultimate frontier of space is the last frontier. Investigation of our solar system is continuing with the exploration of Mars and the New Horizons voyage, which reached the dwarf planet Pluto just before this book was written in 2015. Who could have imagined in 1915 where humanity would have the capacity to go in 2015? The story of those events is contained in both the documentation and the material record of space exploration; it is a history that deserves a fighting chance of being preserved.

Appendix A

Map of Space Heritage Sites

Appendix B

Space Exploration National Historic Landmarks

Reference number	State	Resource name	Address	Date listed
85002807	Alabama	Neutral Buoyancy Space Simulator	George C. Marshall Space Flight Center	October 3, 1985
85002804	Alabama	Propulsion and Structural Test Facility	George C. Marshall Space Flight Center	October 3, 1985
76000341	Alabama	Redstone Test Stand	George C. Marshall Space Flight Center	May 13, 1976
85002806	Alabama	Saturn V Dynamic Test Stand	George C. Marshall Space Flight Center	October 3, 1985
78000500	Alabama	Saturn V Space Vehicle	Tranquility Base	November 22, 1978
66000172	Arizona	Lowell Observatory	1 mile west of Flagstaff on Mars Hill	October 15, 1966
85002816	California	Rogers Dry Lake	Edwards Air Force Base	October 3, 1985
85002814	California	Space Flight Operations Facility	Jet Propulsion Laboratory	October 3, 1985
85002812	California	25-Foot Space Simulator	Jet Propulsion Laboratory	October 3, 1985
85002813	California	Pioneer Deep Space Station	Goldstone Deep Space Communications Complex	October 3, 1985

(*continued*)

Reference number	State	Resource name	Address	Date listed
86003511	California	Space Launch Complex 10	Vandenberg Air Force Base	June 23, 1986
85002799	California	Unitary Plan Wind Tunnel	Ames Research Center	October 3, 1985
84003872	Florida	Cape Canaveral Air Force Station	Launch Pads 5, 6, 13, 14, 19, 26, and 34 and Mission Control Center	April 16, 1984
85002811	Maryland	Spacecraft Magnetic Test Facility	Goddard Space Flight Center	October 3, 1985
85003541	New Mexico	Launch Complex 33	White Sands Missile Range	October 3, 1985
85002801	Ohio	Zero Gravity Research Facility (B-2)	Lewis Research Center	October 3, 1985
85002802	Ohio	Spacecraft Propulsion Research Facility	Lewis Research Center, Plum Brook Station	October 3, 1985
85002815	Texas	Apollo Mission Control Center	Lyndon B. Johnson Space Flight Center	October 3, 1985
85002810	Texas	Space Environment Simulation Laboratory	Lyndon B. Johnson Space Center	October 3, 1985
85002808	Virginia	Lunar Landing Research Facility	Langley Research Center	October 3, 1985
85002809	Virginia	Rendezvous Docking Simulator	Langley Research Center	October 3, 1985
85002795	Virginia	Variable Density Tunnel	Langley Research Center	October 3, 1985

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About the Authors

Lisa Westwood is a registered professional archaeologist (RPA) who has been practicing since 1994 in the fields of cultural resource management, contract archaeology, museum curation, and university teaching. She holds a BA in anthropology from the University of Iowa and an MA in anthropology from Eastern New Mexico University. She currently serves as the director of Cultural Resources at ECORP Consulting Inc., an environmental consulting firm headquartered near Sacramento, California, where she specializes in historical archaeology, including Cold War–era aerospace installations, and regulatory and legal compliance with applicable historic preservation law. She also teaches in the anthropology departments at California State University–Chico and Butte College. It is through her teaching role that Ms. Westwood developed an interest in space heritage. In 2004, she first integrated the concept of space heritage into her college courses, and she has been involving students in the Tranquility Base initiative since that time. She is now regarded as an authority in the emerging field of space heritage and archaeology, particularly with respect to federal preservation frameworks.

Ms. Westwood is a cofounder of the Apollo 11 Preservation Task Force, a volunteer committee of preservation professionals who are working toward designation of Tranquility Base on the moon as a World Heritage site. With colleagues, she led the effort to list the Objects Associated with Tranquility Base on the California Register of Historical Resources, which was achieved in January 2010. This successful effort represents the first time a cultural resource not located on Earth was designated on a historical registry. She has been actively working with members of Congress to have the site designated a National Historic Landmark (NHL). With her colleague, Dr. Beth O'Leary, she is the author of the draft Tranquility Base National Historic Landmark Act. She is engaged in consultations with the International Council on Monuments and Sites (ICOMOS) for eventual inscription on the World Heritage List.

Ms. Westwood recently cochaired and organized the symposia on space heritage at the 2011 and 2013 Society for American Archaeology annual

meetings. Her papers, titled "The Congressional Spyglass: An Alternative View of Historic Preservation . . . on the Moon" and "World Heritage List Designations of Early Space Exploration Heritage Sites," presented the challenges and possible solutions to seeking formal cultural resource management of Tranquility Base from legal, national, and international perspectives. She has been featured or appeared in numerous media reports and interviews, including the television program *California Life with Heather Dawson,* Reuters International, the *Washington Post,* NASA and the Smithsonian Institution's Key Moments in Human Spaceflight Symposium, and *Space Times* magazine, among many others. She was the cohost of *Video News* on the Archaeology Channel for three seasons.

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Dr. Beth Laura O'Leary is a recently retired professor in the Department of Anthropology, New Mexico State University, Las Cruces. From 2003 to 2011 she served as the governor-appointed vice chair of the Cultural Properties Review Committee. For the past sixteen years she has been involved with the cultural heritage of outer space and the preservation of sites related to space exploration. A recipient of a grant from the New Mexico Space Grant Consortium (NASA), she investigated both the archaeological assemblage and the international heritage status of the Apollo 11 Tranquility Base site on the Moon.

Dr. O'Leary is a recognized expert in the emerging field of space archaeology and heritage and has been interviewed by the media in the United States, Canada, Europe, Australia, and China. She created a radio essay on space archaeology for BBC Radio 3. Dr. O'Leary has cochaired four international symposia on space archaeology and heritage in Australia, Great Britain, Canada, and the United States. In 2010, through the efforts of Dr. O'Leary and her colleagues and graduate students, the objects and structures at Apollo 11 at Tranquility Base were placed on both the California and New Mexico registers of cultural properties.

In 2009, she published *Handbook of Space Engineering, Archaeology, and Heritage* with coeditor Ann Darrin. In January 2011, she was an invited expert by NASA at the Kennedy Space Center to participate in writing "NASA's Recommendations to Space Faring Entities: How to Protect and Preserve the Historic and Scientific Values of US Government Artifacts." She received an award from NASA for her work in 2012.

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Mr. Milford Wayne Donaldson is the president of award-winning Architect Milford Wayne Donaldson, FAIA, Inc. since 1978, specializing in historic

preservation services. He is licensed to practice architecture in California, Nevada, and Arizona and holds a certified license from the National Council of Architectural Registration Boards. Mr. Donaldson is affiliated with several historical and preservation organizations and is a past president of the California Preservation Foundation (CPF) and past chair of the State Historical Building Safety Board, the State Historical Resources Commission, and the Historic State Capitol Commission.

Mr. Donaldson served as the California state historic preservation officer (SHPO) from 2004 to 2012. During his tenure as SHPO, he streamlined the Section 106 process of the National Historic Preservation Act and led the national initiative toward the sustainability and greening of historic resources. On June 1, 2010, Mr. Donaldson was appointed chair of the Advisory Council on Historic Preservation by President Barack Obama and currently holds that position.

Previously an instructor at California Polytechnic State University, San Luis Obispo, he continues to lecture at California community colleges and universities. Mr. Donaldson holds a Bachelor of Architecture and a Bachelor of Science in engineering from California Polytechnic State University, San Luis Obispo. He engaged in postgraduate studies at Uppsala University, Sweden, and received a Master of Science degree in architecture from University of Strathclyde, Glasgow, Scotland, and a Master of Arts degree in public history and teaching from the University of San Diego.

Over the past thirty-five years, Mr. Donaldson has established himself as a leader in historic preservation and adaptive reuse of existing structures. Mr. Donaldson's firm, mainly throughout the western portion of the United States, has completed more than three thousand projects. His depth of knowledge unites nineteenth-century building methods with state-of-the-art twenty-first-century construction technologies. In 1991, the California Council of the American Institute of Architects acknowledged Mr. Donaldson for his statewide leadership in the interpretation of the California Historical Building Code that allowed the rehabilitation of historic buildings. In 1992, the American Institute of Architects inducted Mr. Donaldson into the College of Fellows. He has written several articles on the preservation of historical resources located on Department of Defense military installations.

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